

Decentralized Stormwater Management Techniques in Urban Areas

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**Cahill Associates
Environmental Consultants
www.thcahill.com**







Recapping some stormwater basics....



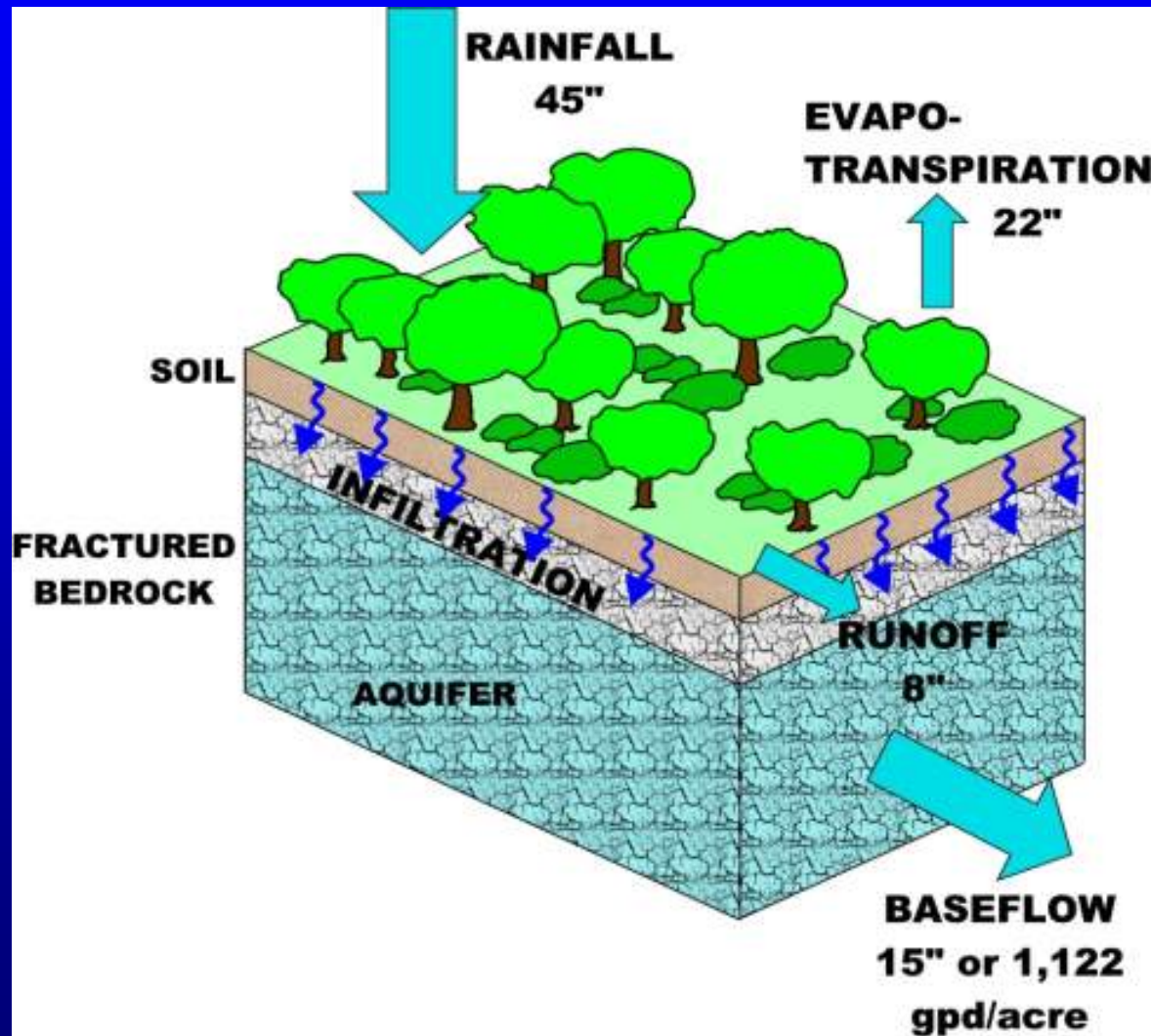
Impacts of Impervious Area

- Increased **Rate** of Runoff
 - Flash Flooding
- Increased **Volume** of Runoff
 - Reduced Infiltration
 - Increased Streambank Erosion
- Increased **Pollutant** Loadings
 - Temperature Changes
 - Loss of Aquatic diversity

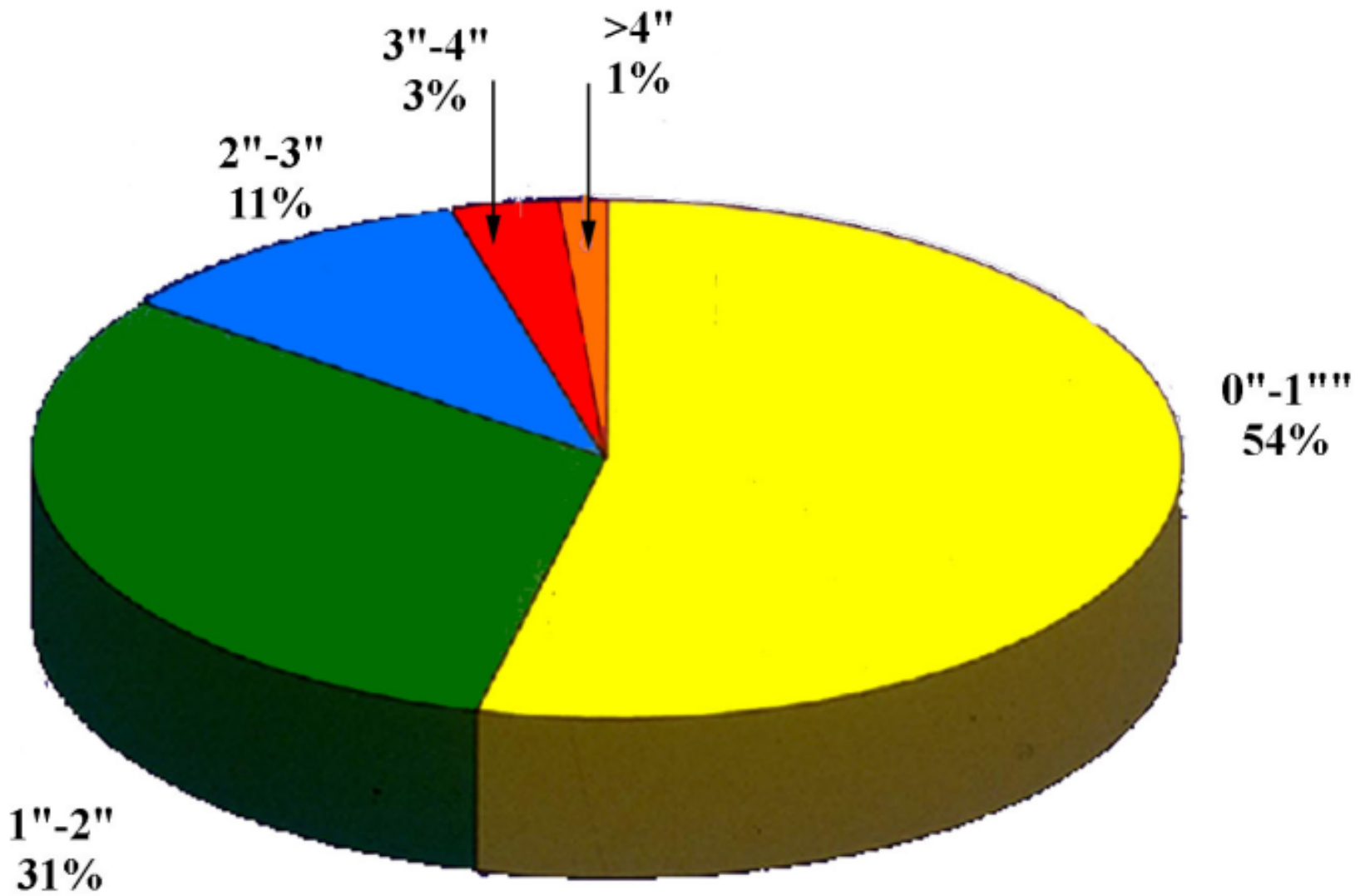


Annual Hydrologic Cycle

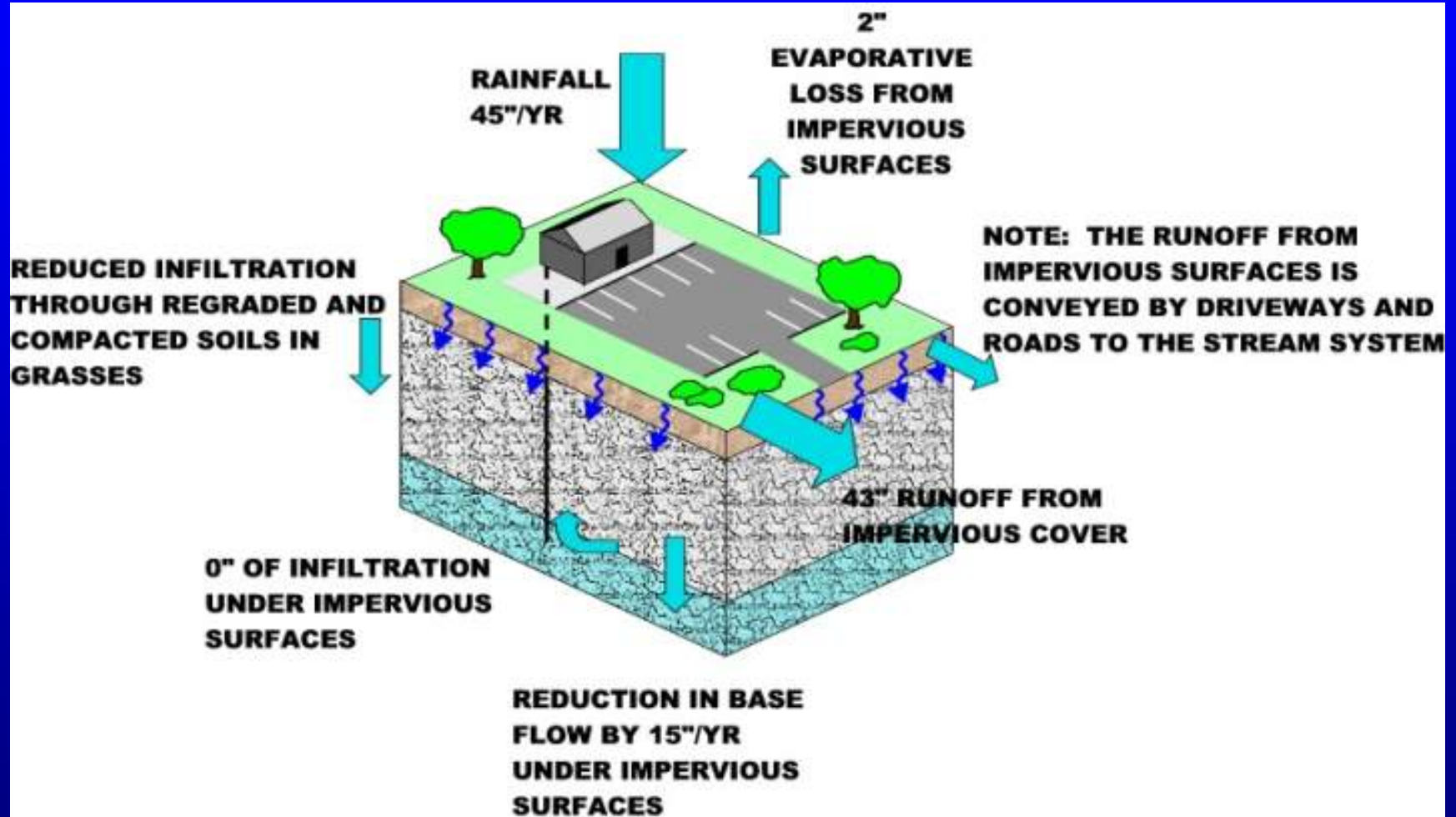
For an Average Year



DISTRIBUTION OF RAINFALL BY EVENT MAGNITUDE



Altered Hydrologic Cycle



Stormwater BMP Challenges in Urban Areas

1. High densities of imperviousness (50% to 100%).
2. High property values, limited physical space, or lot-line to lot-line development.
3. Compacted soils, contamination.
4. Underground utilities: gas, steam, sanitary, building foundations.
5. Severely impacted streams, original streams enclosed/buried in culverts.
6. Elimination of much of the original floodplain through placement of fill and structures.



Stormwater BMP Challenges in Urban Areas (con't)

7. Direct connection of impervious surfaces
8. Combined sanitary-storm sewers.
9. High levels of trash, debris and pet waste.
10. Stormwater “hot spots” : industrial areas, vehicle service areas, public works storage areas, dumpsters, etc.
11. Regulations and ordinances that may conflict with current BMP design strategies.
12. Limited economic resources, and the need to encourage – not discourage- redevelopment.



In Urban Areas Make Stormwater a Part of the Built Environment

- **Parking Areas**
- **Sidewalks**
- **Planting Beds**
- **“Green” Conveyance Elements**
- **Roofs**

Physical Space and Economics are key.

Dual Use is especially important.



Successful Case Studies: Decentralized Stormwater Management in Urban Areas

Seeing is Believing



Springbrook Farms

Hershey, PA

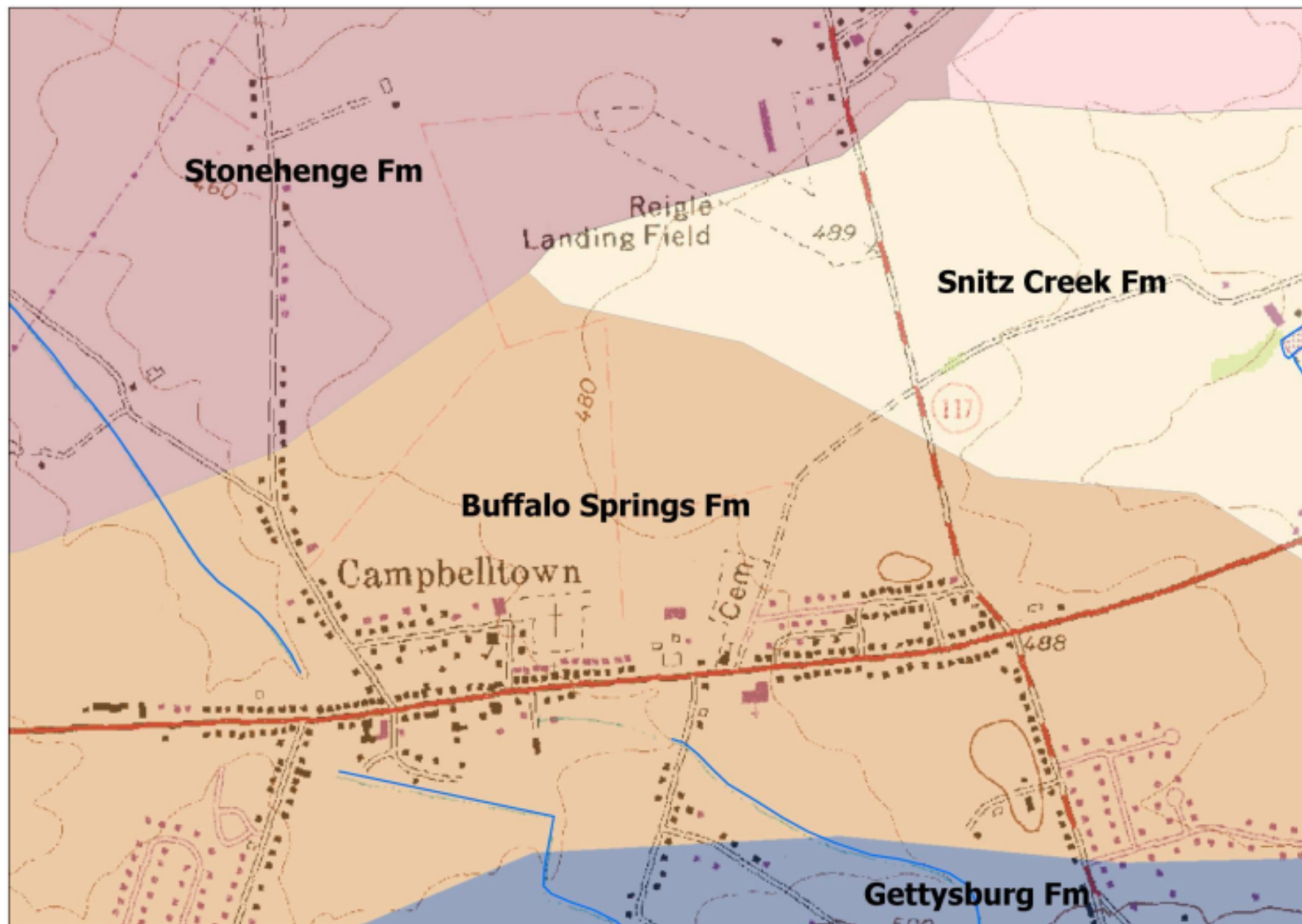
- 280 units on 80 acres
- Limestone geology – sinkhole fears
- Initial design with detention basins
- Redesigned with distributed infiltration beds
- 127 separate beds beneath pavements and open space
- Flow routing difficult for 100-year rainfall



SOUTH LONDONDERRY TOWNSHIP, LEBANON COUNTY, PENNSYLVANIA

Springbrook Residential Development

GEOLOGY







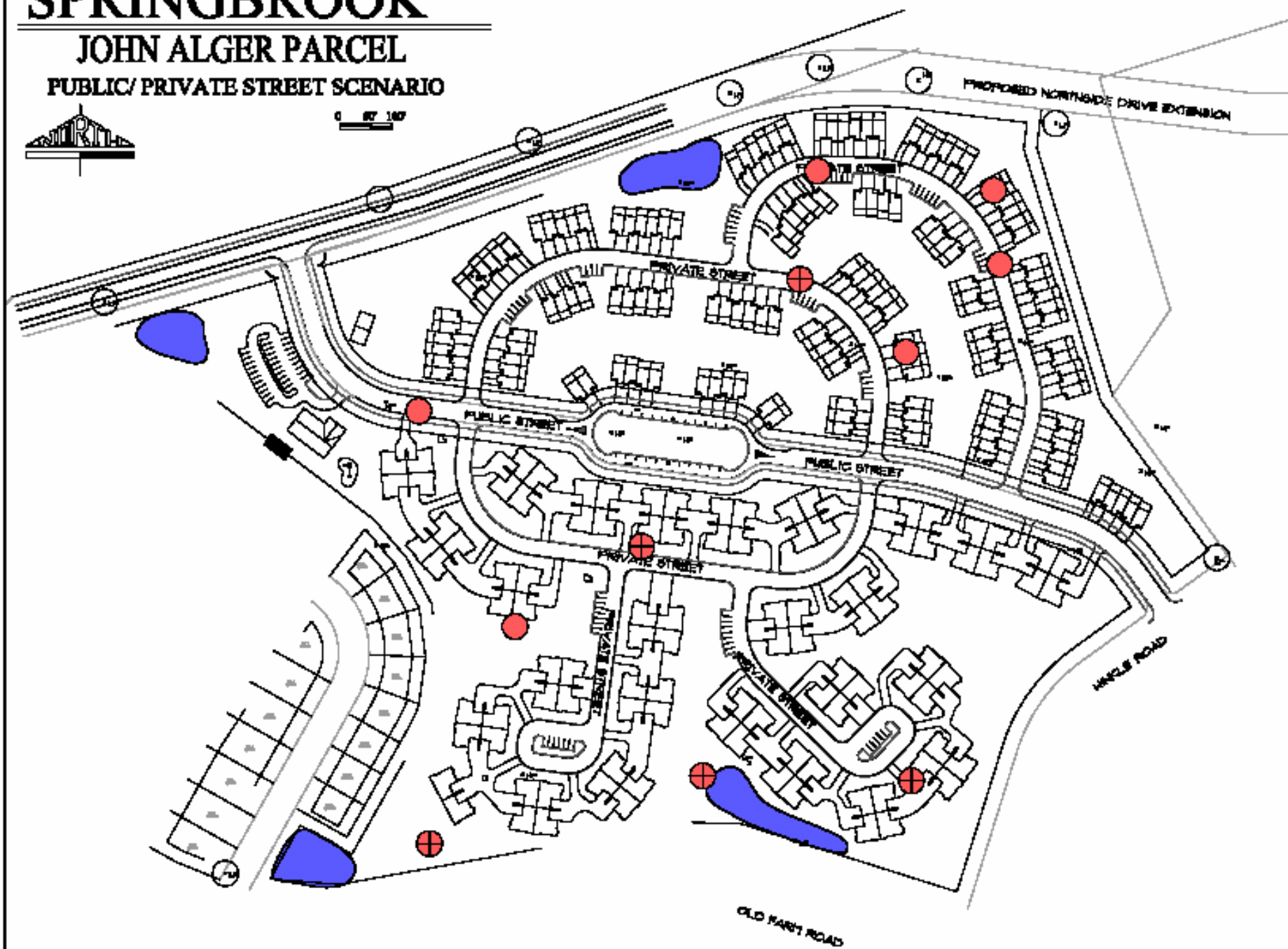
SPRINGBROOK

JOHN ALGER PARCEL

PUBLIC/ PRIVATE STREET SCENARIO



0 87 167



General Stormwater Strategy

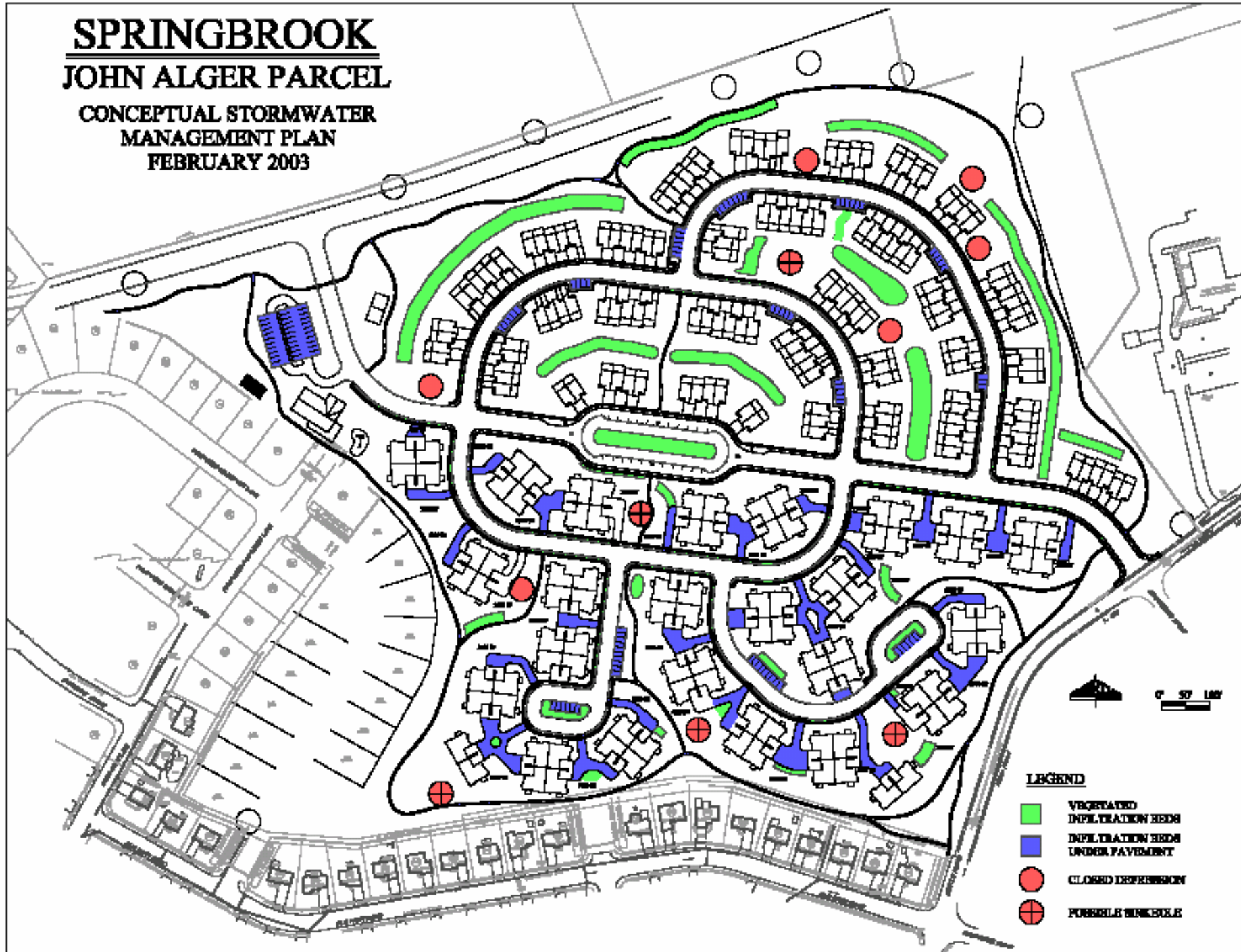
- Maintain or reduce existing volumes of runoff
- Use distributed infiltration and vegetated system (proven strategies that minimize risk of subsidence)
- Avoid building on or near closed depressions and sinkholes
- Minimize cut and fill to maximize available soil mantle



SPRINGBROOK

JOHN ALGER PARCEL

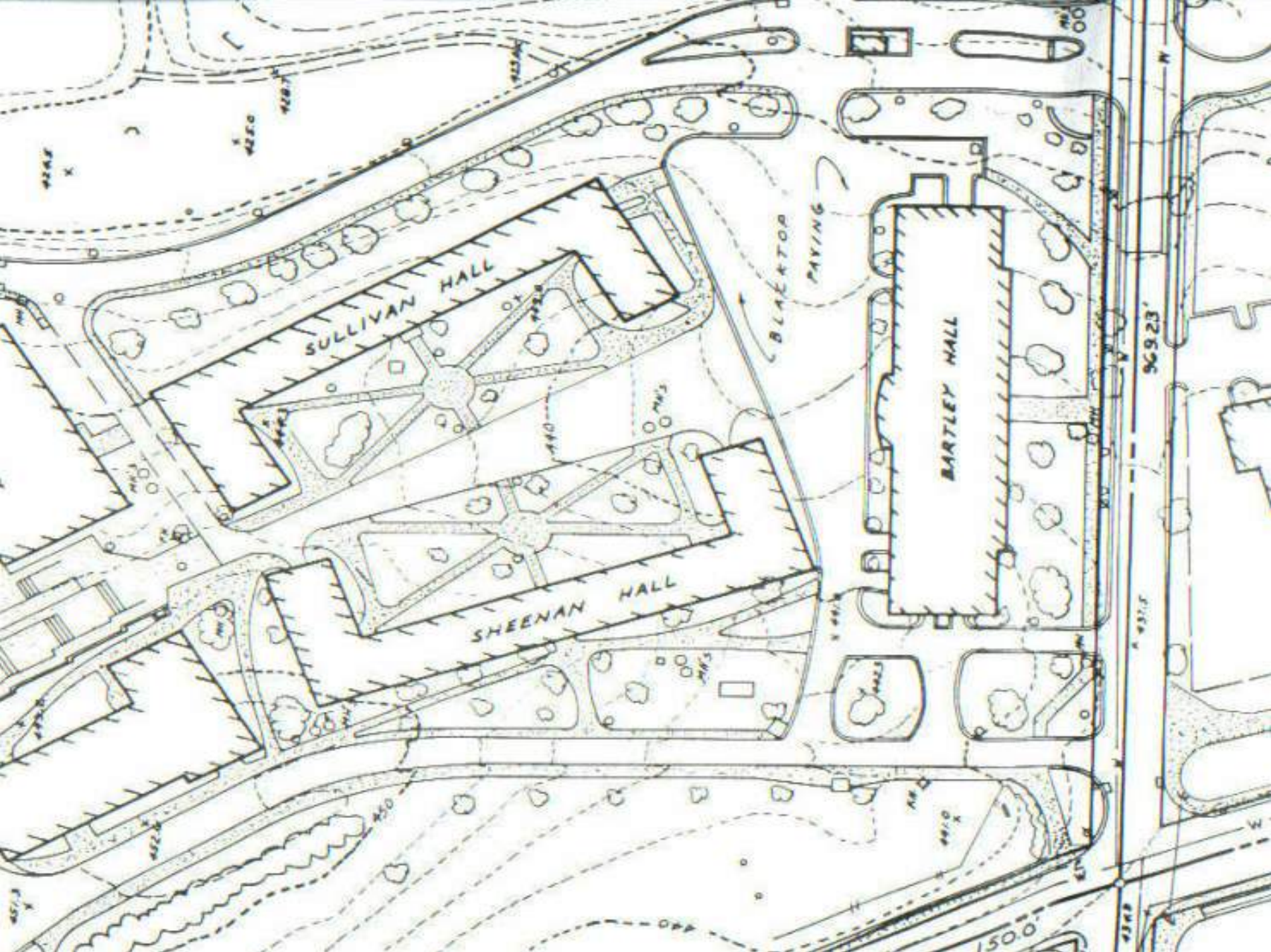
CONCEPTUAL STORMWATER
MANAGEMENT PLAN
FEBRUARY 2003



Bartley Hall Plaza Villanova University Radnor Twp. PA

- Porous Concrete Plaza; Recharge Bed
- Retrofit
- Education and Research for Students; Area Demonstration Project





SULLIVAN HALL

SHEENAN HALL

BARTLEY HALL

BLASIOR

PAVING

96923'

937.5'

1500'





Bartley Hall Plaza, Villanova University

- 1. A stone storage/infiltration bed was placed beneath the entire plaza, with roof leaders connected directly to the bed.**
- 2. The perimeter of the plaza was paved in porous concrete. Rainfall runs off the brick and standard concrete and drains through the porous concrete.**







8/2/02





Penn State Visitor Center State College, PA

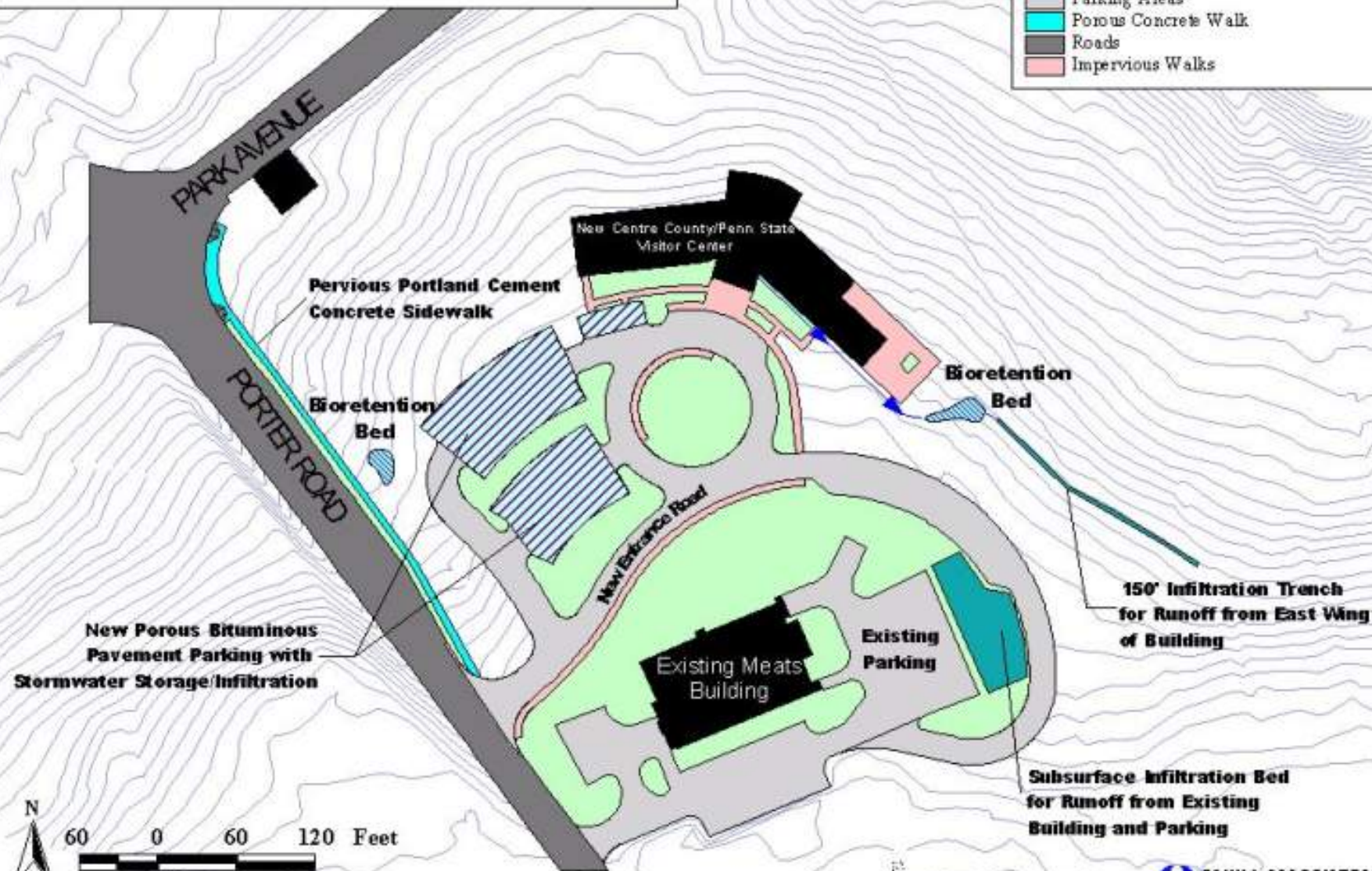
- **A sub-surface vegetated infiltration bed that receives runoff from an existing building and parking lot**
- **Porous bituminous pavement in the parking areas, underlain by a stone filled storage/recharge bed**
- **New sidewalks constructed of porous concrete**
- **Bioretention basins – small depressions carefully planted to improve water quality**
- **Shallow infiltration trenches that receive roof runoff**



CENTRE COUNTY
and
PENNSYLVANIA STATE UNIVERSITY
VISITOR CENTER

SCHEMATIC STORMWATER MANAGEMENT DESIGN

- Topography
-  Stormwater Bioretention Beds
 -  Porous Pavement with Recharge Beds
 -  Stormwater Infiltration Trenches/Beds
- Structures
-  Buildings
 -  Grass & Horticultural Plantings
 -  Parking Areas
 -  Porous Concrete Walk
 -  Roads
 -  Impervious Walks



The image shows the exterior of a modern building with a prominent wooden pergola structure over the entrance. The building has a mix of stone, wood, and glass. A large white banner is hung across the entrance. The entrance itself consists of several glass doors with dark frames. Above the doors, there is a small sign. To the right of the entrance, there are some trash bins and a tall light pole. The foreground is a paved area, and the background shows more of the building and some landscaping.

Welcome to the
Centre County/Penn State Visitor Center

Centre County/Penn State Visitor Center
OPEN DAILY 9:00AM - 5:00PM

Paying Attention to our Water Supply

Water moves continuously through a process called the hydrological cycle. Rain and snow fall to the ground where they filter into the earth or run off to our streams, lakes, and oceans. This water then either evaporates or is absorbed by plants that release water vapor through their leaves through transpiration. The vapor condenses and falls to earth again as rain or snow. The cycle then repeats itself as water is captured by plants and further runs the ground to the sea or to the ocean.

Water in this cycle is completely like the spaces between soil particles in rocks and is known as groundwater. Areas of groundwater that contain enough water to support wells are called aquifers. Groundwater is continuously in the move and eventually discharges into a spring, stream, lake or wetland.

Sustainable management

One way to protect our aquifers from pollutants is to manage the runoff from our roads, parking lots, and roofs. Until recently, stormwater management focused on funneling excess water off of a site and into streams to alleviate flooding. In recent years, as issues of quantity, not quality. We have become increasingly aware of the need to protect our aquifers from these types of pollutants and new methods of managing stormwater are being developed.

The Hydrological Cycle



How the Visitor Center Manages Water



Here at the Visitor Center we have implemented some innovative systems to help maintain or improve the quality of our groundwater.

Hard surfaces such as rooftops, roads and parking lots prevent rainwater from joining our natural water storage systems (aquifers) in a healthy manner. With conventional paving systems, rainwater washes across these surfaces, picking up pollutants from vehicles such as leaking antifreeze and oil, and is then channeled into drainage pipes for discharge into our streams and rivers or directed into holding ponds to be discharged later. These systems bypass the natural filtering provided by plants, their root systems, rocks and soils. Not only does the water carry pollutants into the aquifer, the water temperature is also higher than normal, causing excessive plant growth in our streams and choking off the oxygen supply necessary for aquatic life. Also, the volume and velocity of the water discharged in one place (such as a pipe outlet) can carve away stream banks, sending sediment downstream to further disrupt plant and animal life.

We can keep our water systems healthier by allowing rainwater to enter the aquifer as close to where it falls as possible. This allows the water to seep through the natural filtering system and be dispersed into streams and lakes at a healthy pace. The Visitor Center is designed to do just that.

Penn State Visitor Center









Rain Garden

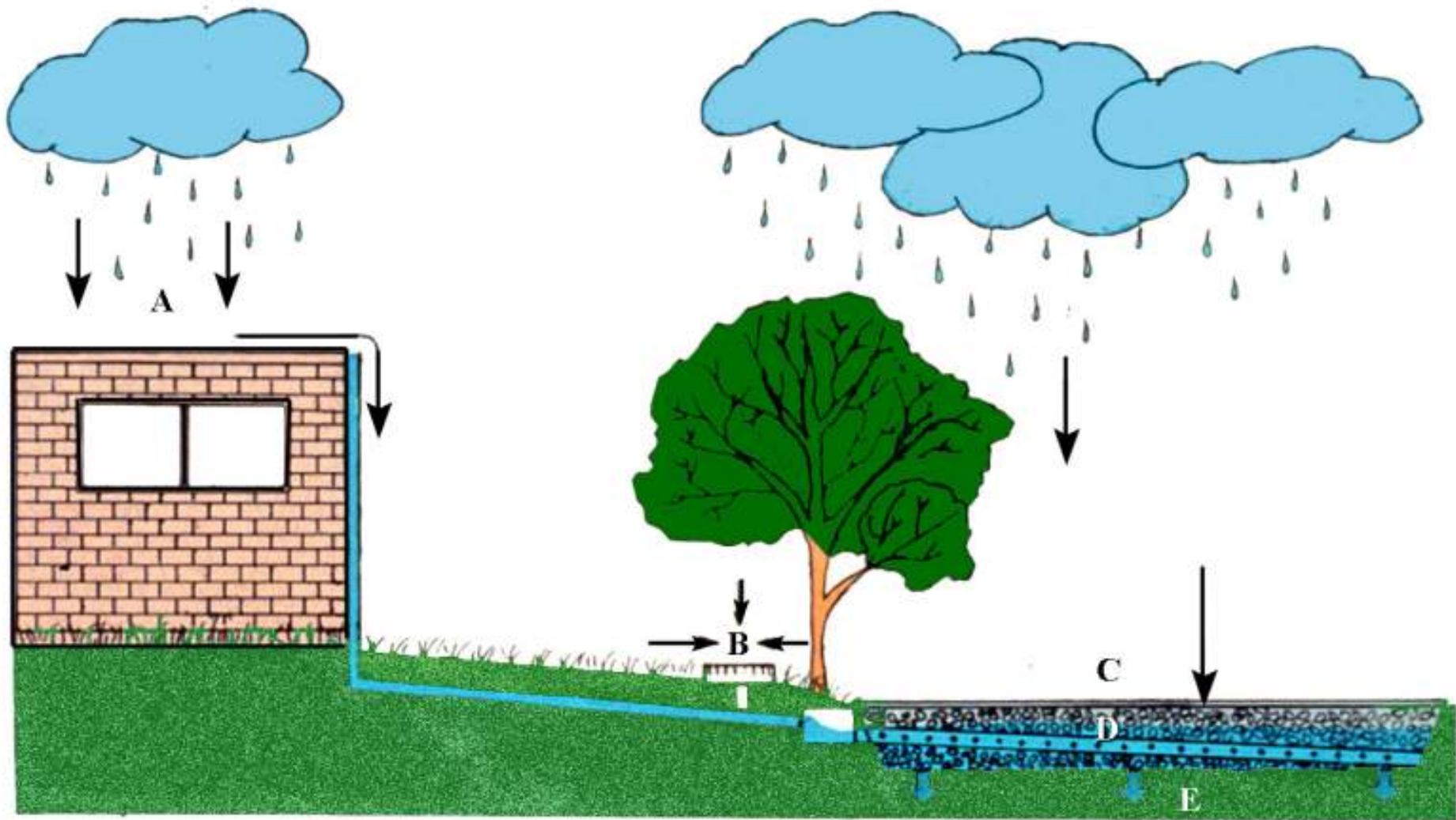
Rain Gardens & Water Quality Swales

- Integrate Landscape and Stormwater
- Improve Water Quality
- Allow runoff to infiltrate
- Some shallow water during storms





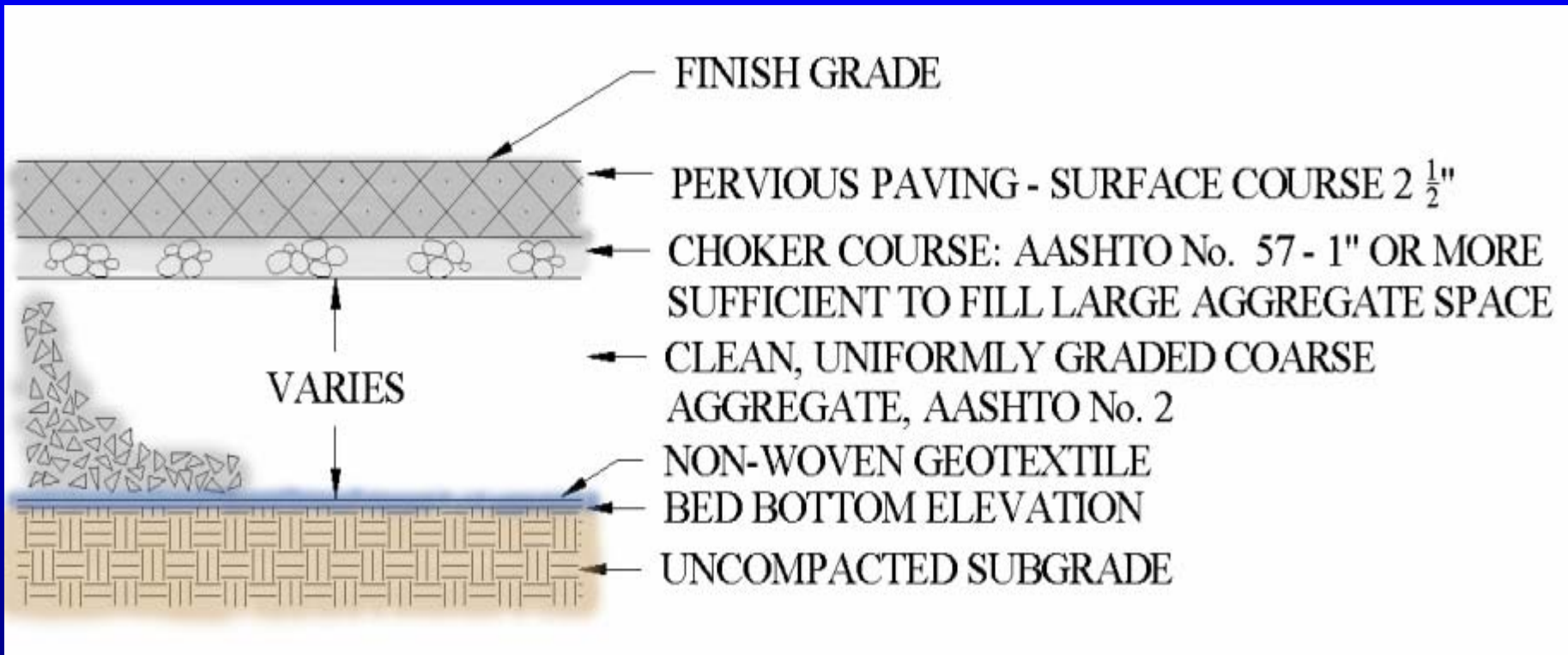




- A.** Precipitation is carried from roof by roof drains to storage beds.
- B.** Stormwater runoff from impervious and lawn areas is carried to storage beds.
- C.** Precipitation that falls on porous paving enters storage beds directly
- D.** Stone beds with 40% void space store water. Continuously perforated pipes distribute stormwater from impervious surfaces evenly throughout the beds.
- E.** Stormwater exfiltrates from storage beds into soil, recharging groundwater.



Porous or Standard Paving w/ Infiltration







10. 9. 2002

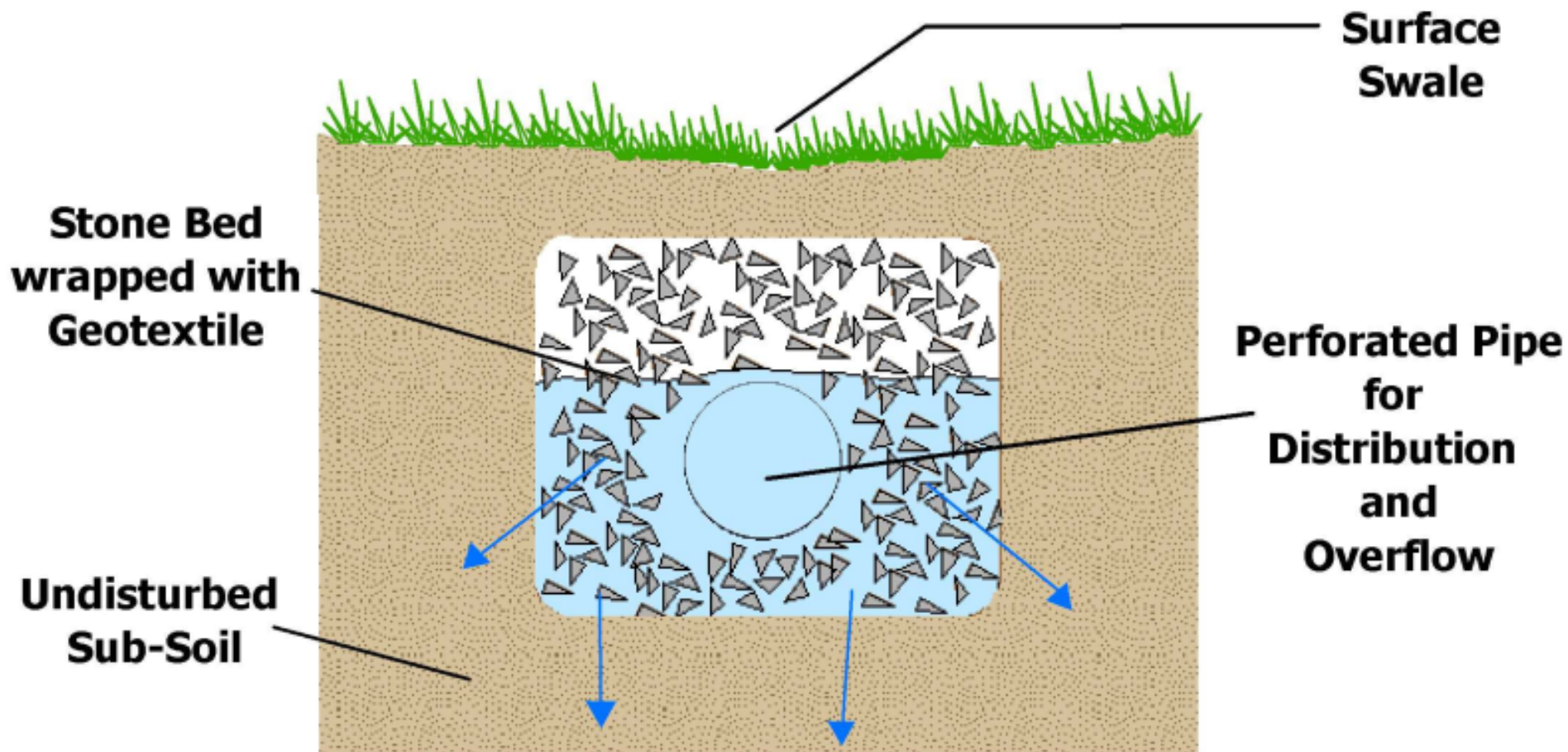


Penn State University Park Porous Concrete Sidewalks

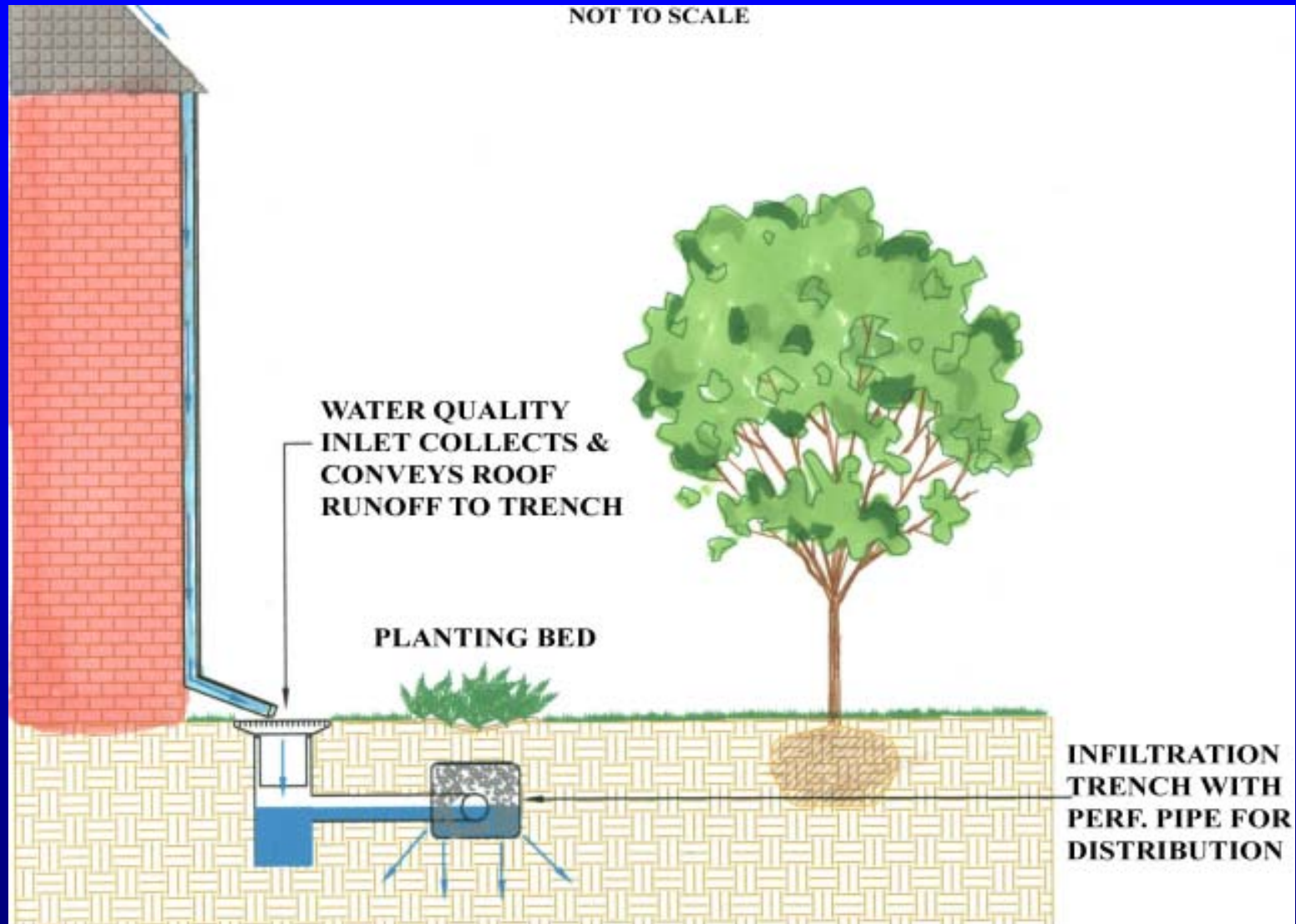




INFILTRATION TRENCH



Infiltration Trench Under Planted Area





Infiltration Trench



Infiltration Berms

- Simple construction along contour
- Capture runoff behind shallow berm
- Allow runoff to infiltrate
- Very little disturbance

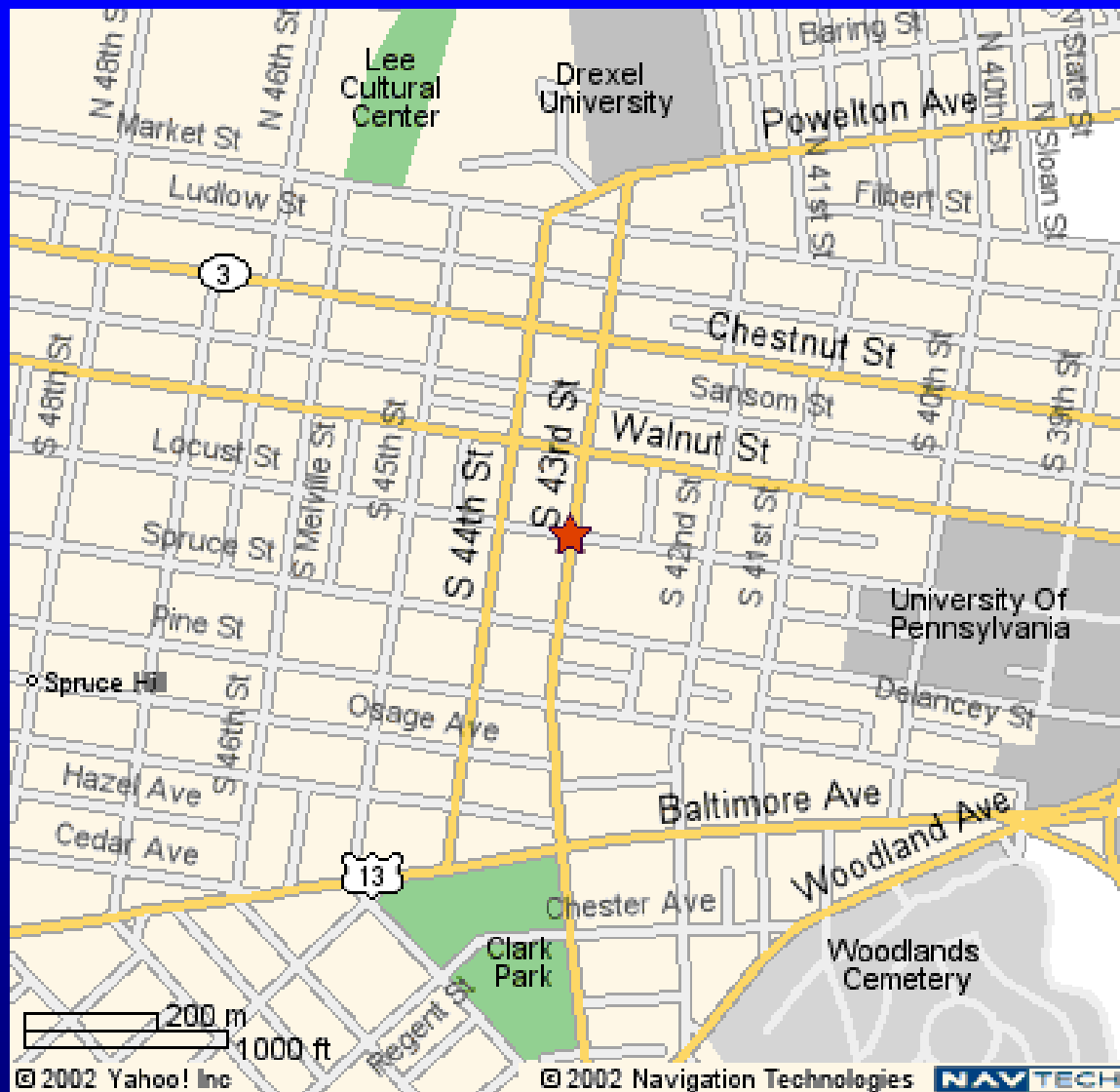


Penn New School

43rd and Locust Streets

- PADEP Growing Greener & Philadelphia Water Department
- Porous Pavement Play Yard
- Infiltration Bed Beneath Athletic Field
- Rain Gardens and Native Vegetation
- Environmental Education







Mill Creek Watershed





Burying of Mill Creek – Late 1800's









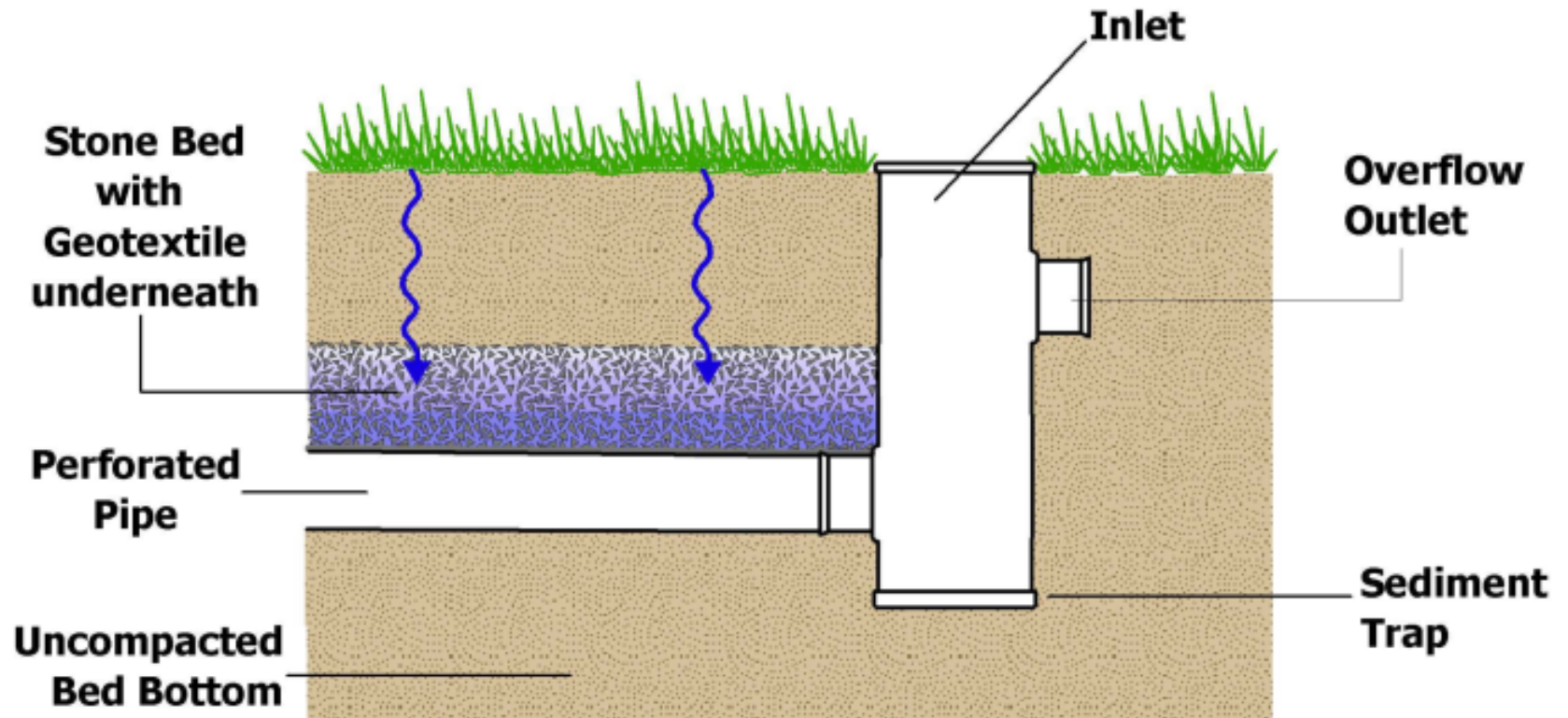
Porous Pavement Playfield Philadelphia





Playfield “before”

INFILTRATION BED





Playfield “after” with Subsurface Stormwater Bed

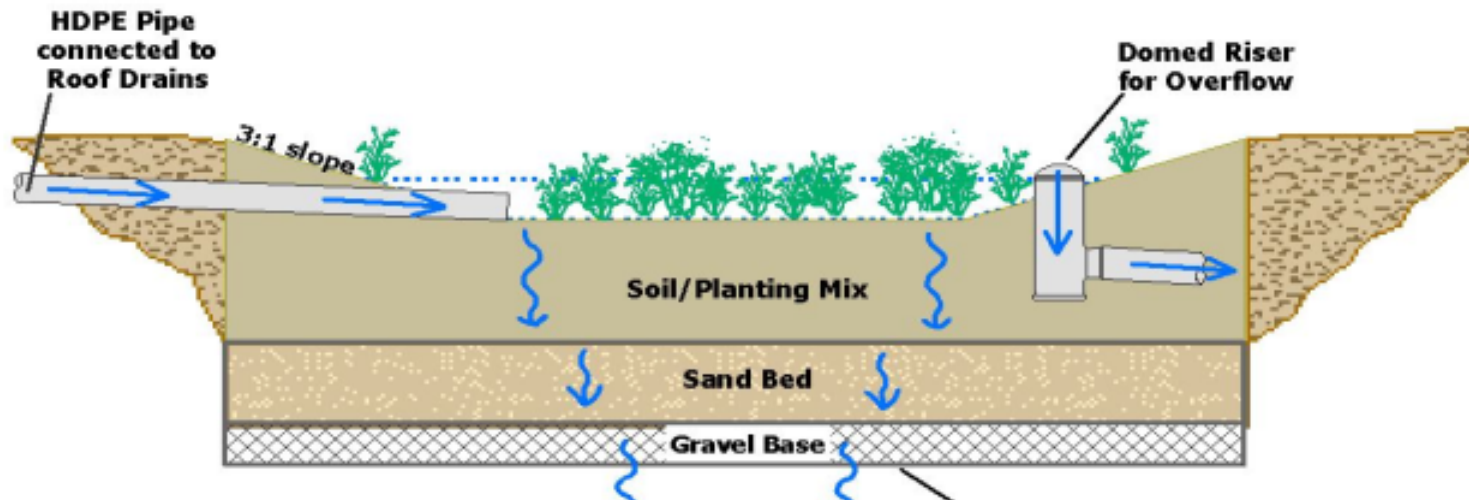


Rain Gardens & Vegetated Swales

- Modified Soils
- Depression Storage
- Native Plantings
- Reduced Fertilization



RAIN GARDEN / BIORETENTION BED

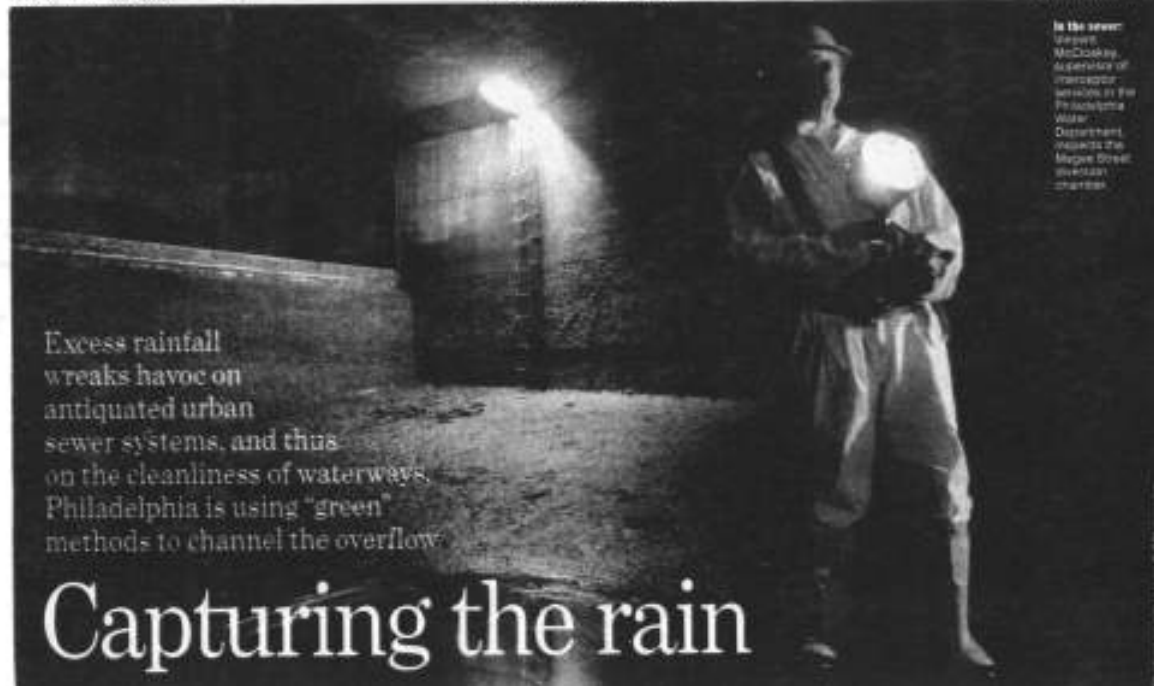


MONDAY, MAY 26, 2003

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The Philadelphia Inquirer

WWW.PHILLY.COM



In the sewer:
 Steven
 McCoskey,
 supervisor of
 interceptor
 systems in the
 Philadelphia
 Water
 Department,
 inspects the
 Magway Street
 section.
 CHARLES FOX

Excess rainfall
 wreaks havoc on
 antiquated urban
 sewer systems, and thus
 on the cleanliness of waterways.
 Philadelphia is using "green"
 methods to channel the overflow.

Capturing the rain

By Tom Avril
 INQUIRER STAFF WRITER

To most people, the green field behind the charter school is a good place to play soccer.

For Howard Neukrug, it is a way to keep raw sewage from flowing into the river.

Under the grass lies a sophisticated drainage system — pipes and 18 inches of gravel — that can absorb nearly 45,000 gallons of rainwater in just a few hours.

Every drop of water that goes into the ground behind the West Philadelphia school is a drop that doesn't flow into the street and down the drain to the city's aging sewage treatment system.

For in much of Philadelphia — as in Camden, Baltimore, Pittsburgh, New York and more than 700 older cities in the United States — rain and human wastes travel through the same pipes.

If there is too much rain, the sewers can't handle the strain, and raw sewage overflows into waterways.

Many older cities have agreed to spend staggering sums to reduce overflow from these "combined sewers," often prompted by government or activists' lawsuits. Boston, Atlanta and Washington each are expected to spend more than \$1 billion in the coming years.

So far, Philadelphia has escaped a big financial hit, partly because it has been spending money on smaller upgrades all



CHARLES FOX / Inquirer Staff Photographer

Under the grass at the Penn Alexander school in West Philadelphia is a drainage system that absorbs rainwater and keeps it out of overtaxed sewage pipes. Howard Neukrug, watersheds director in the city Water Department, shows one of the drains.

along and partly because the city's declining population has meant fewer flushing toilets and more sewer capacity, according to local and federal officials.

And partly — according to Neukrug, head of the watersheds office in the city Water Department — the credit is due to projects such as the field behind the new

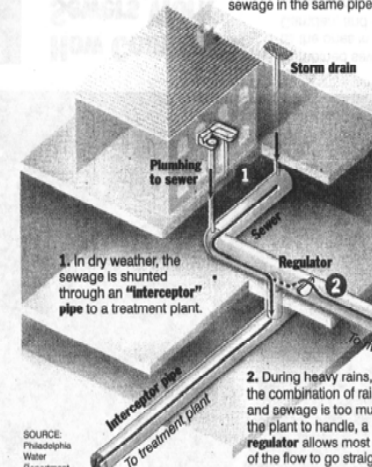
Sadie Tanner Mossell Alexander University of Pennsylvania Partnership School.

It wasn't cheap — funded by a \$250,000 state grant, which also paid for a nearby "rain garden" and a play area covered with porous, water-absorbing pavement.

But such efforts are better than spend. See **SEWERS** on E10

How Combined Sewers Work

Combined sewer systems, as the ones in Philadelphia, Camden, and other old cities collect rainwater and human sewage in the same pipes.





Washington National Cathedral

Washington National Cathedral, D.C.

- Cathedral and Parking on top of hill
- Surrounded by “Olmsted’s Woods”
- Point Discharges eroding hillside
- Lack of Recharge: Diminished Soil Moisture and Dying Trees
- Invasive Vegetation



Existing Outfall from Pilgrim Road





13 11 2002

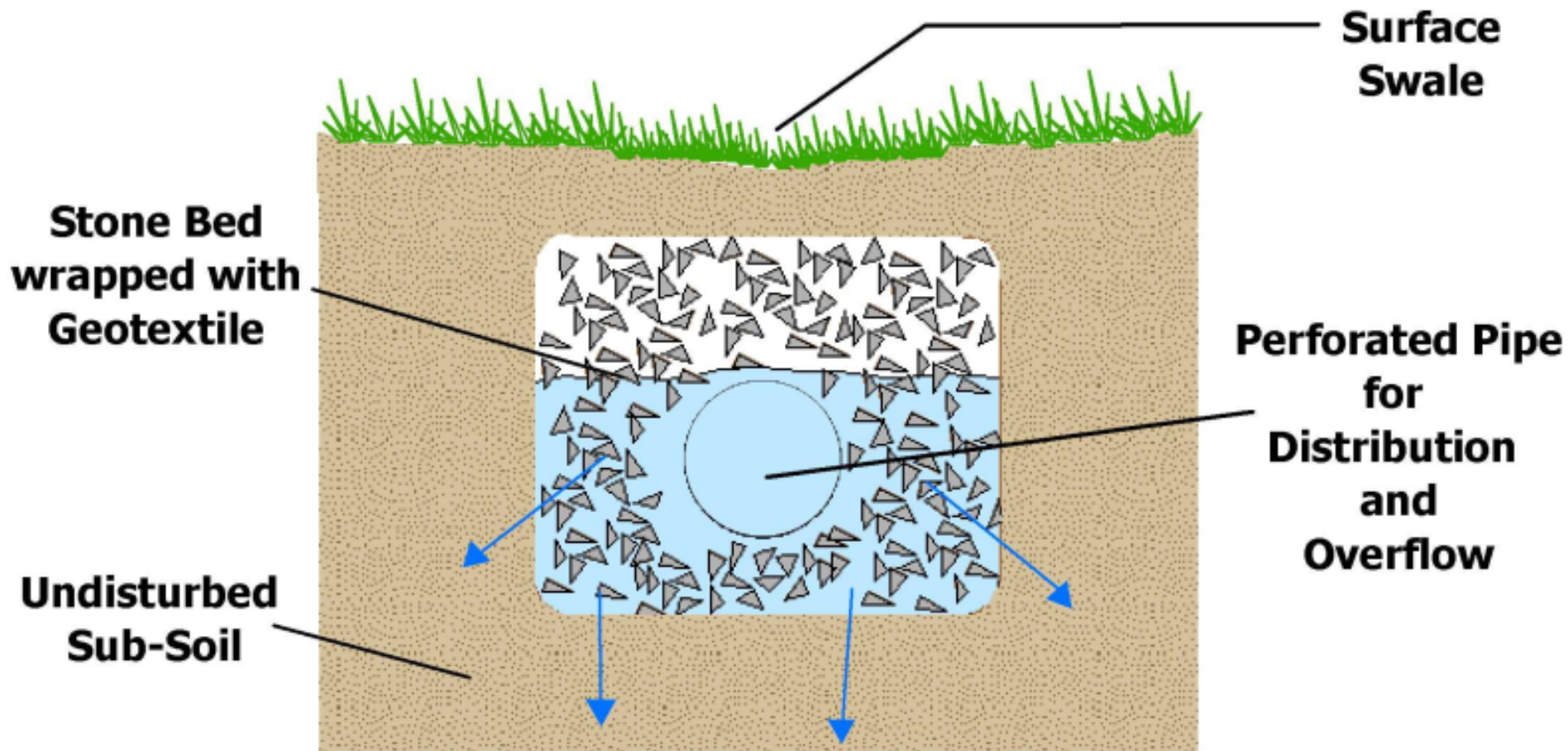




Infiltration Trenches



INFILTRATION TRENCH









Rainstore³

ACF Environmental Inc.

*"BMP Solutions for Storm
Water Management"*



Stacked Into Cells cells of 25 unit each 2.5 meters tall (8.2 feet)



Cells Assembled
At Manufacturing
Facility — To custom
height (from 0.1 m to 2.5 m)









13.11.2002



University of North Carolina Chapel Hill

- Campus wide program
- Local Ordinances
- 70% impervious





UNC Chapel Hill

Stormwater Management Program

BMP Applications

June 18, 2002

North Campus

Legend

Watersheds

Structural BMP'S

Tree Trenches

Infiltration Bed

Open Water

Porous Pavement

Runoff Reuse

Water Quality Inlets

Vegetated Roof

Potential Rain Garden

Landscape BMP's

Old Field

Unfertilized Planting Area

Land Cover

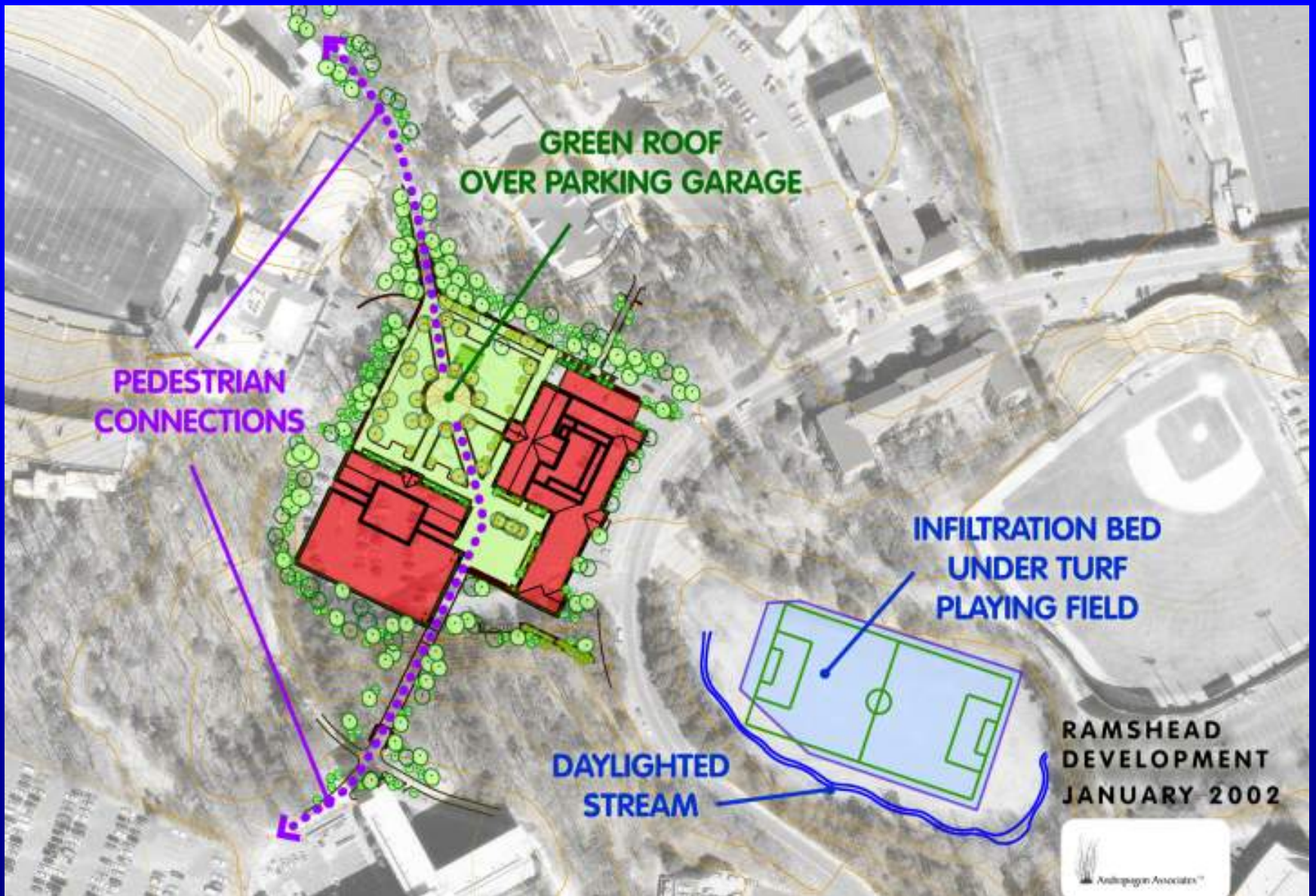
New Buildings

Roads & Parking

Buildings

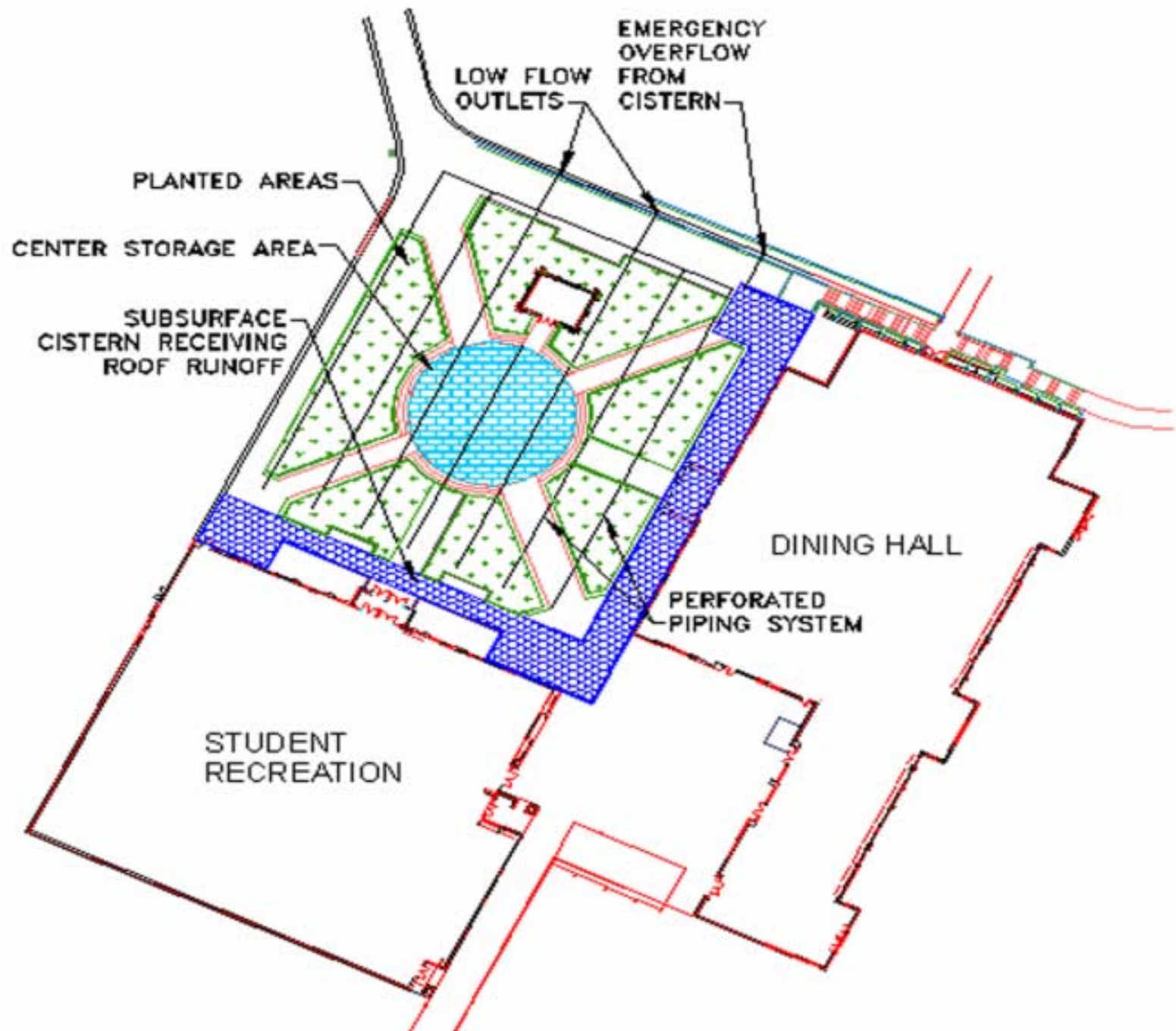
Walkways

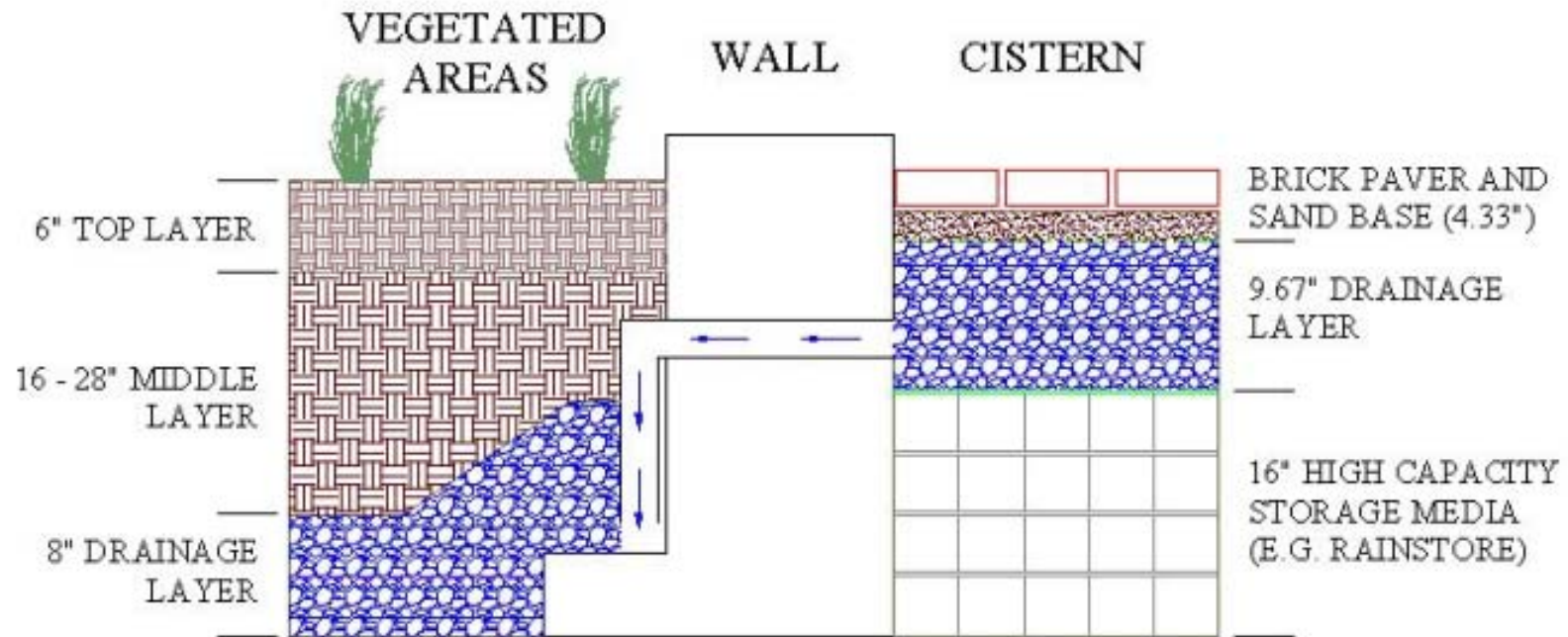




Ramshead Site Plan
















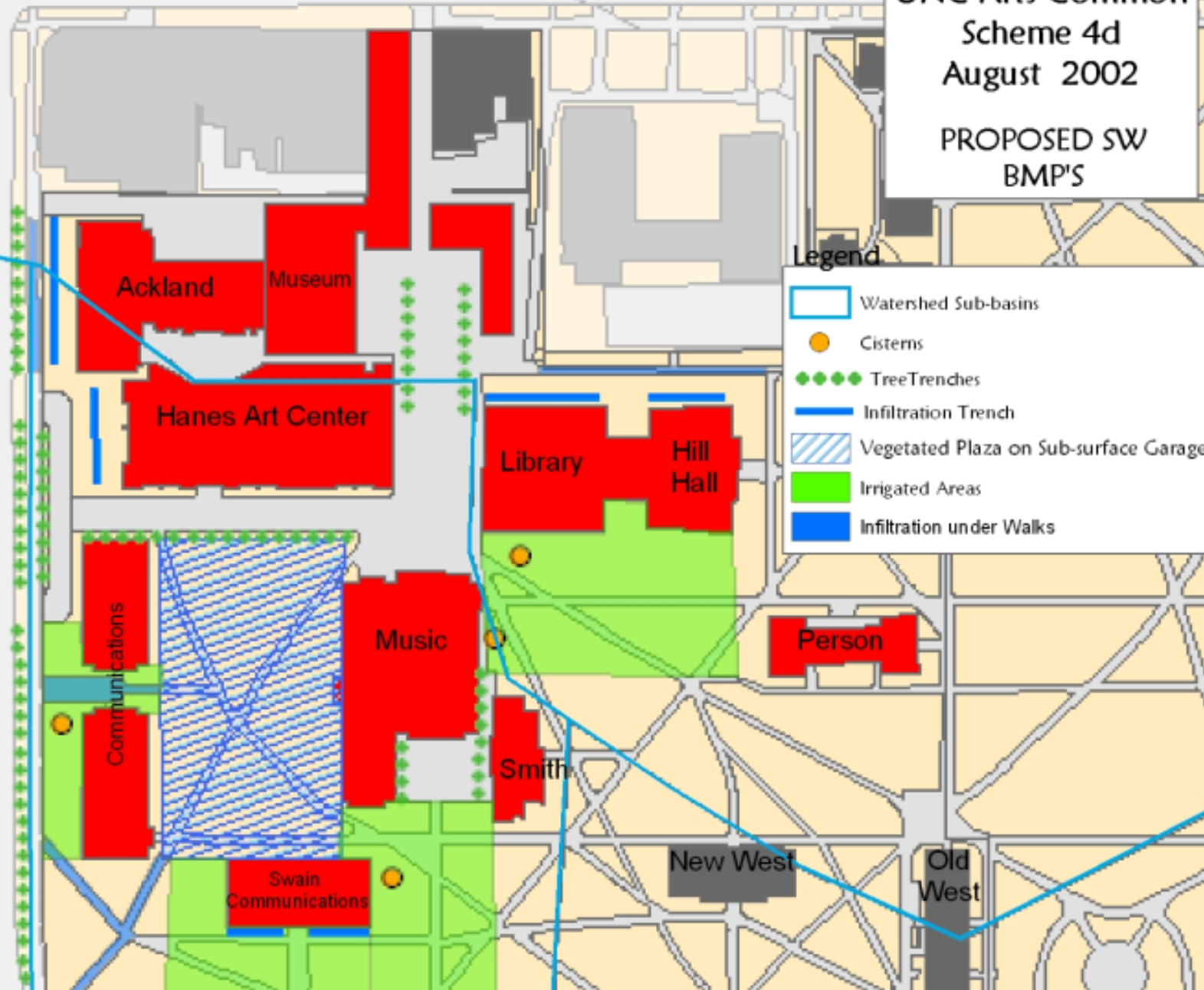
Carmichael Field Site Plan



UNC Arts Common
Scheme 4d
August 2002
PROPOSED SW
BMP'S

Legend

-  Watershed Sub-basins
-  Cisterns
-  TreeTrenches
-  Infiltration Trench
-  Vegetated Plaza on Sub-surface Garage
-  Irrigated Areas
-  Infiltration under Walks



*Conceptual Plan, Not Intended to Represent Actual Design Locations.

UNC-CH Arts Common
Stormwater Management Plan





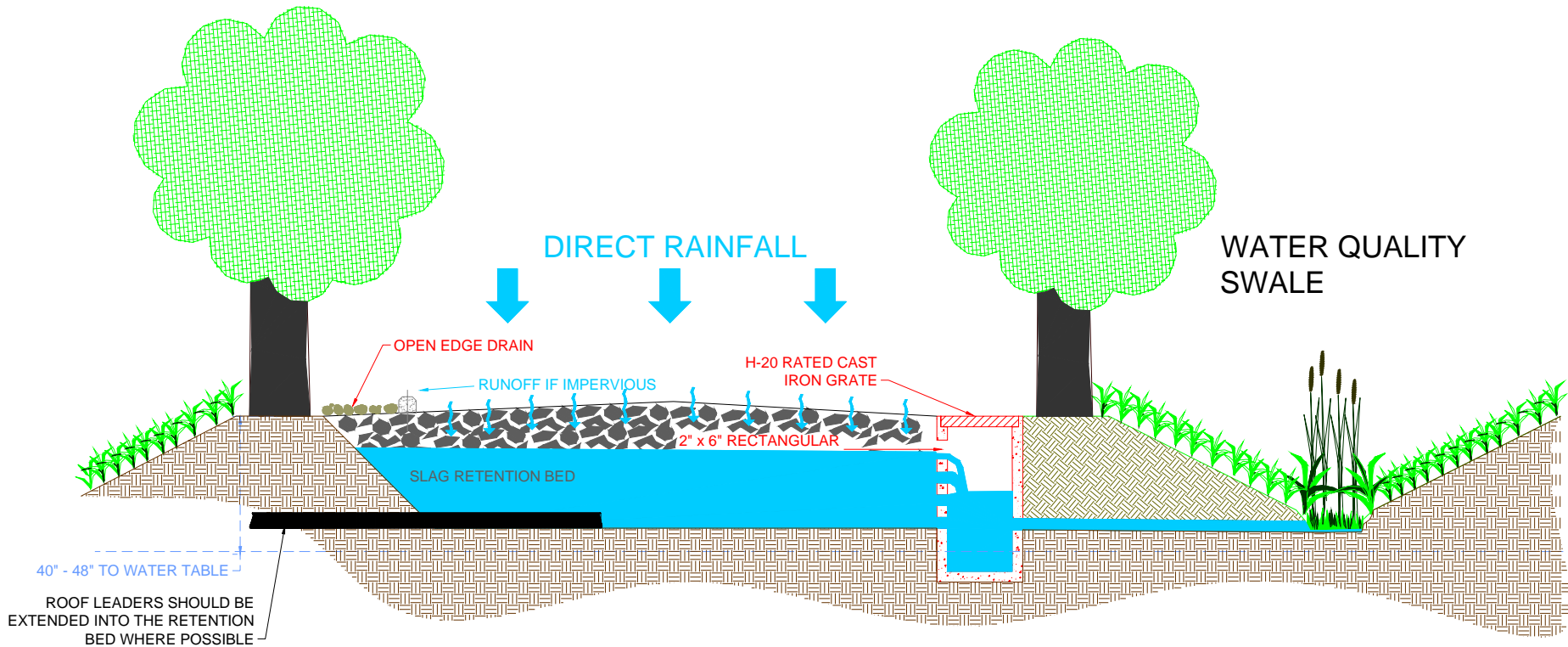
Ford Rouge Center Dearborn, Michigan

Ford Rouge Center 1952



Artist Richard Rochon's rendering of an aerial view of the Ford Rouge Center that includes the new Ford assembly plant.

Strategy for Water Quality





**Decontaminated slag,
recycled from on-site**





Vegetated Infiltration Swale

Stormwater surface storage and infiltration through vegetated layer and planting layer for water quality treatment

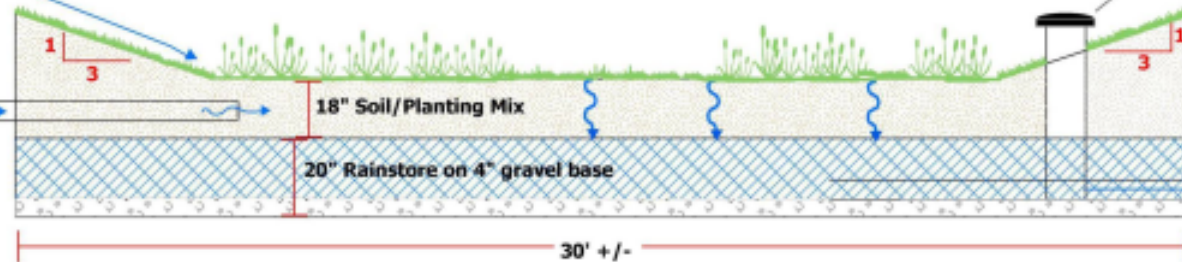
Conceptual only: drawing not to scale



Discharge of untreated stormwater to planting area (either surface runoff from roads/parking or point discharges)

High flow discharge to storm sewer

Discharge of untreated stormwater into soil mix via perforated distribution pipes



Discharge to swale or storm sewer

Modify width as needed based on available area and coordination with landscape plan.

NOTE: Rainstore system can serve as cistern for irrigation needs as desired.



Vegetated swale near Visitor's Center



Ford Rouge Assembly Building



-World's largest green roof – 10.4 ac







**1: Porous
pavement w/
subsurface
storage**

**2: 10.4 ac of
green roof**

**3: Porous
pavement w/
infiltration**

**4: Vegetated
water quality
swales**



Ford Rouge 2003

**Other Urban Techniques....
if time allows.**

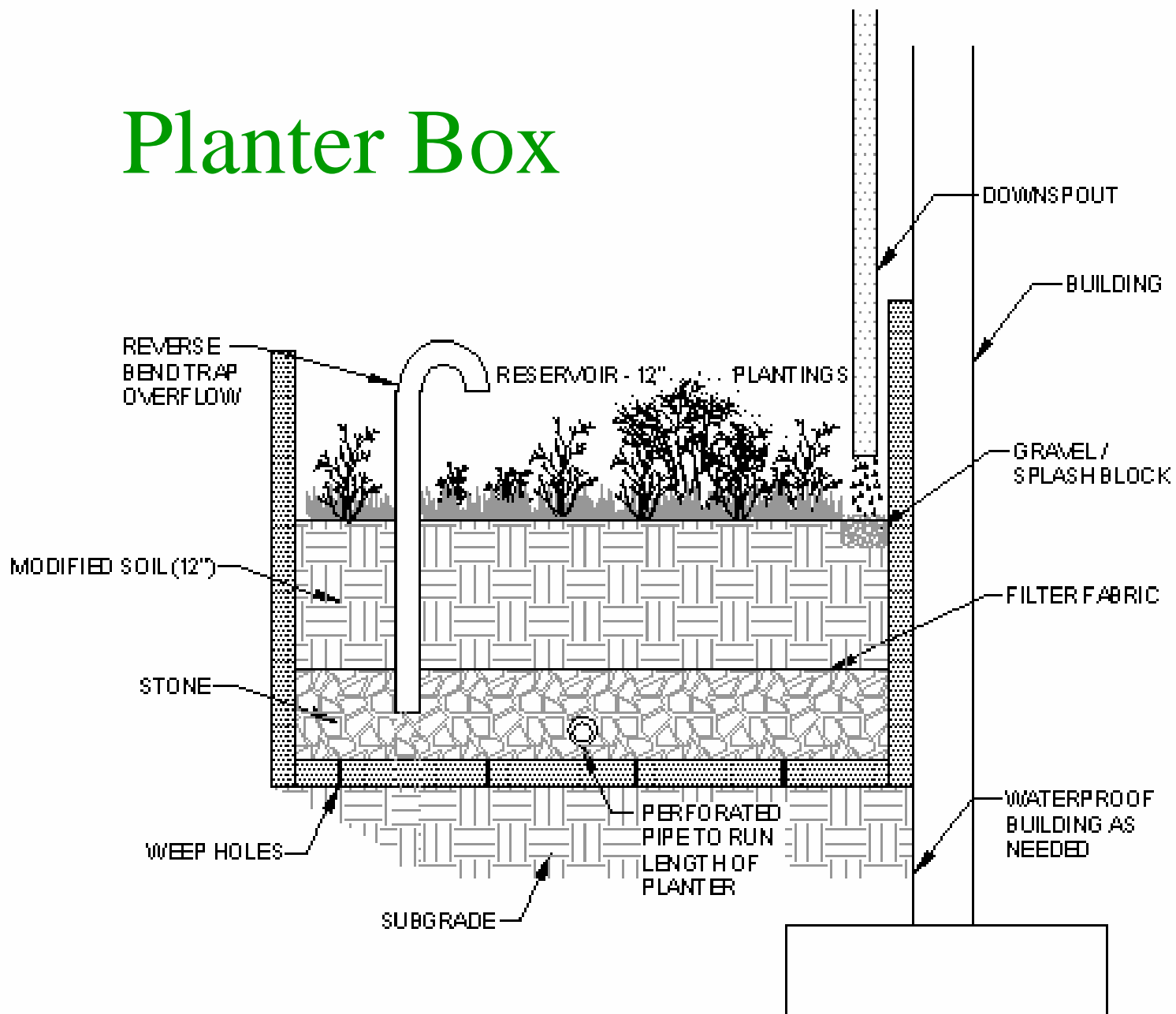


Stormwater Planter Box

- Portland Manual
- Holds runoff for a period of time
- Aesthetic
- Easy to set up
- Relatively inexpensive



Planter Box



Possible Planter box area



Rain Barrels

- 60-gallon Rain Barrel holds ~ 8 cf
- 2 Rain Barrels ~ 16 cf



Rain Barrel opportunities



Porous Pavement

- Over 100 installations
- Oldest systems 1980-82
 - DuPont, Verizon, SmithKline, Siemen's
 - National Park Service, Fish & Wildlife, National Forest Service
 - Libraries, Religious Centers, Prisons
 - Industrial – Ford and Alcoa
 - Office Parks, Shopping Malls, Municipal Buildings



Porous Pavement

Schools

- Penn State: State College and Berks Campus
- University of Rhode Island (2) – 1,000 cars
- University of North Carolina (2) 1,500 cars
- Penn New School in Philadelphia - playground
- St. Joseph's in Downingtown, PA
- Springside School in Philadelphia
- Swarthmore College - paths
- University of Michigan
- Villanova – Porous Concrete





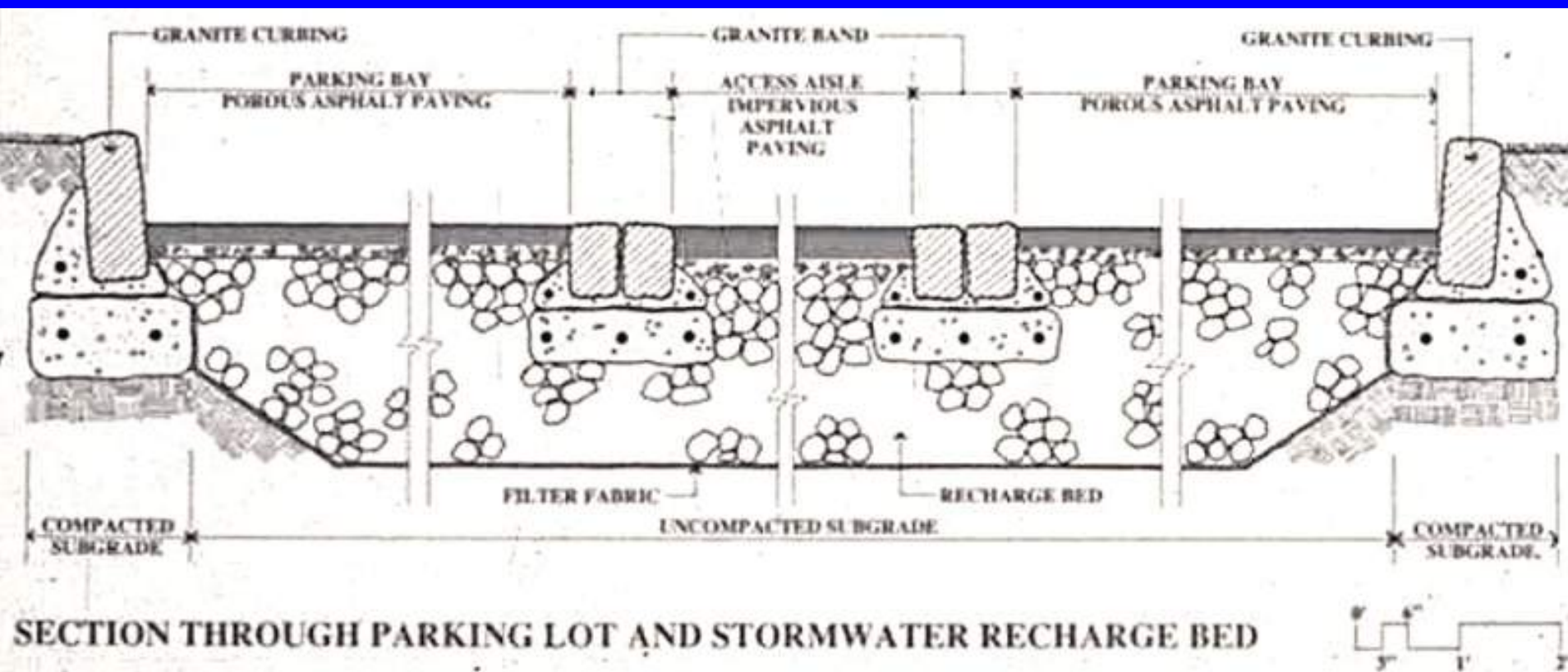
Morris Arboretum





*Photo of parking - Morris
Arboretum, Phila*

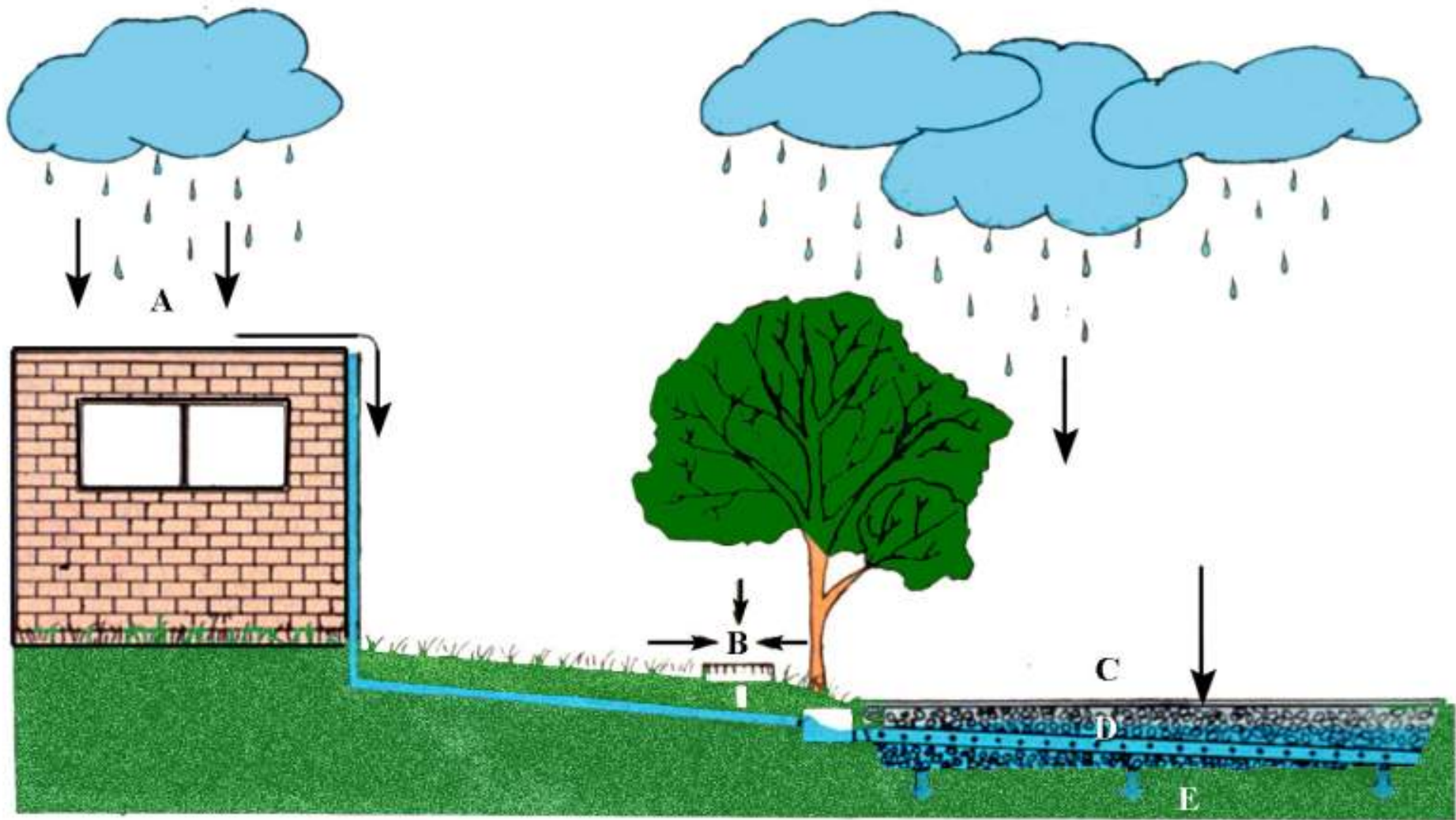




*Diagram of infiltration bed
at Morris Arboretum*



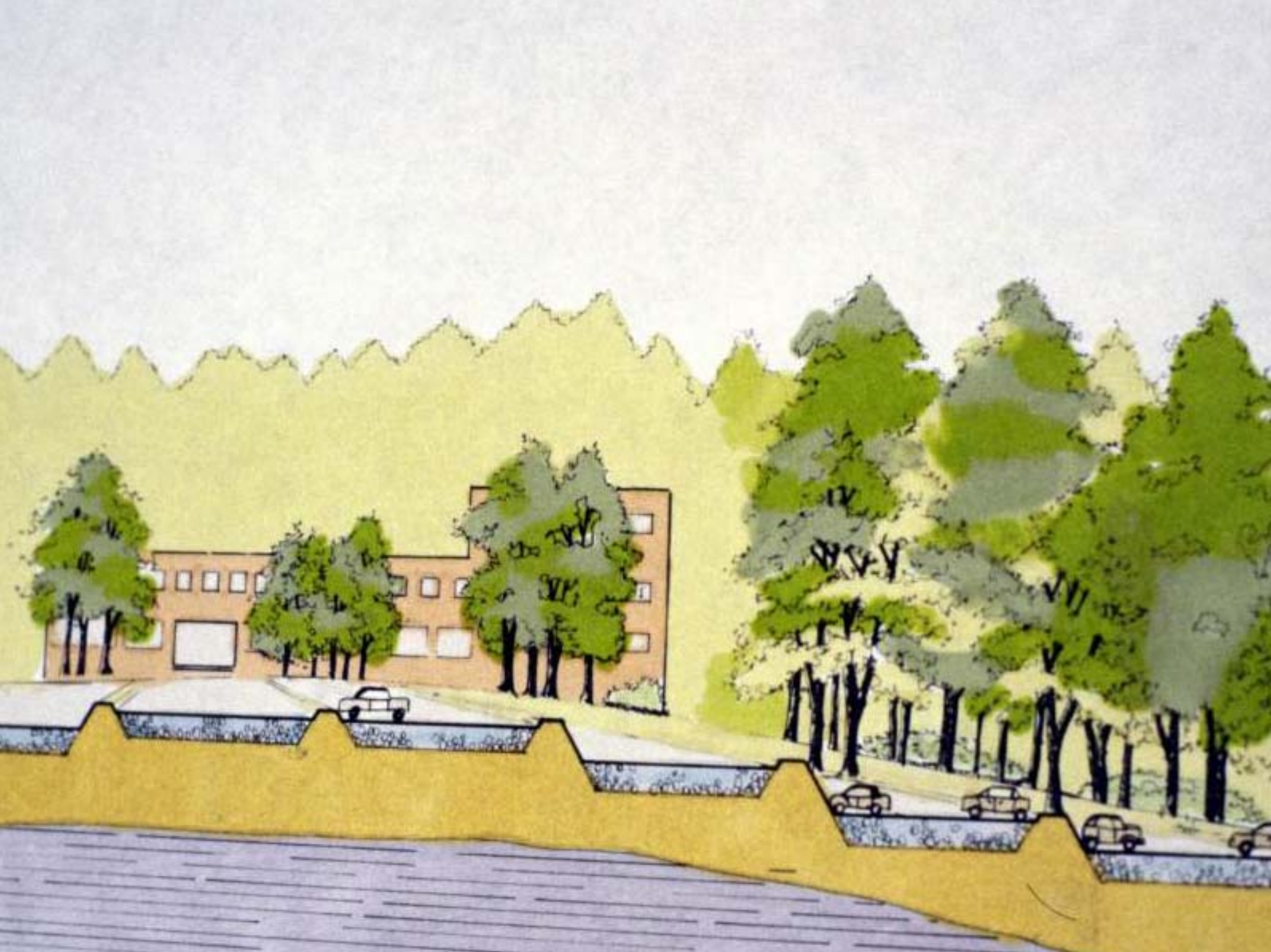




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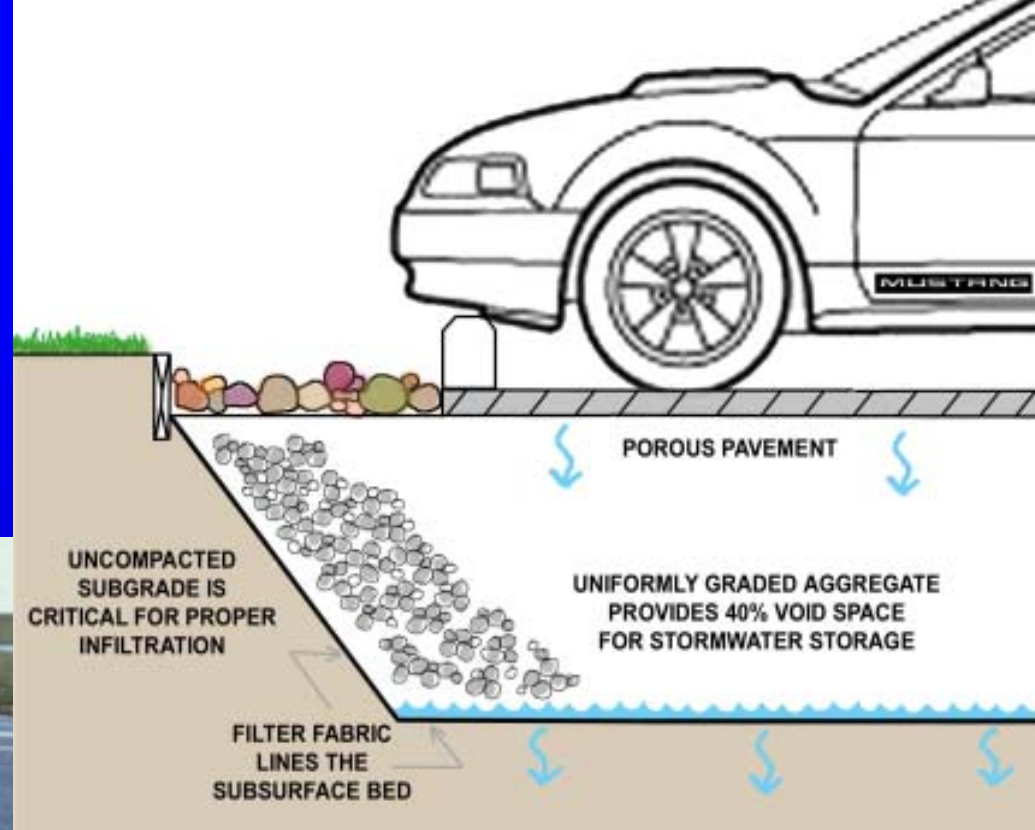








Siemens Corporation 1983

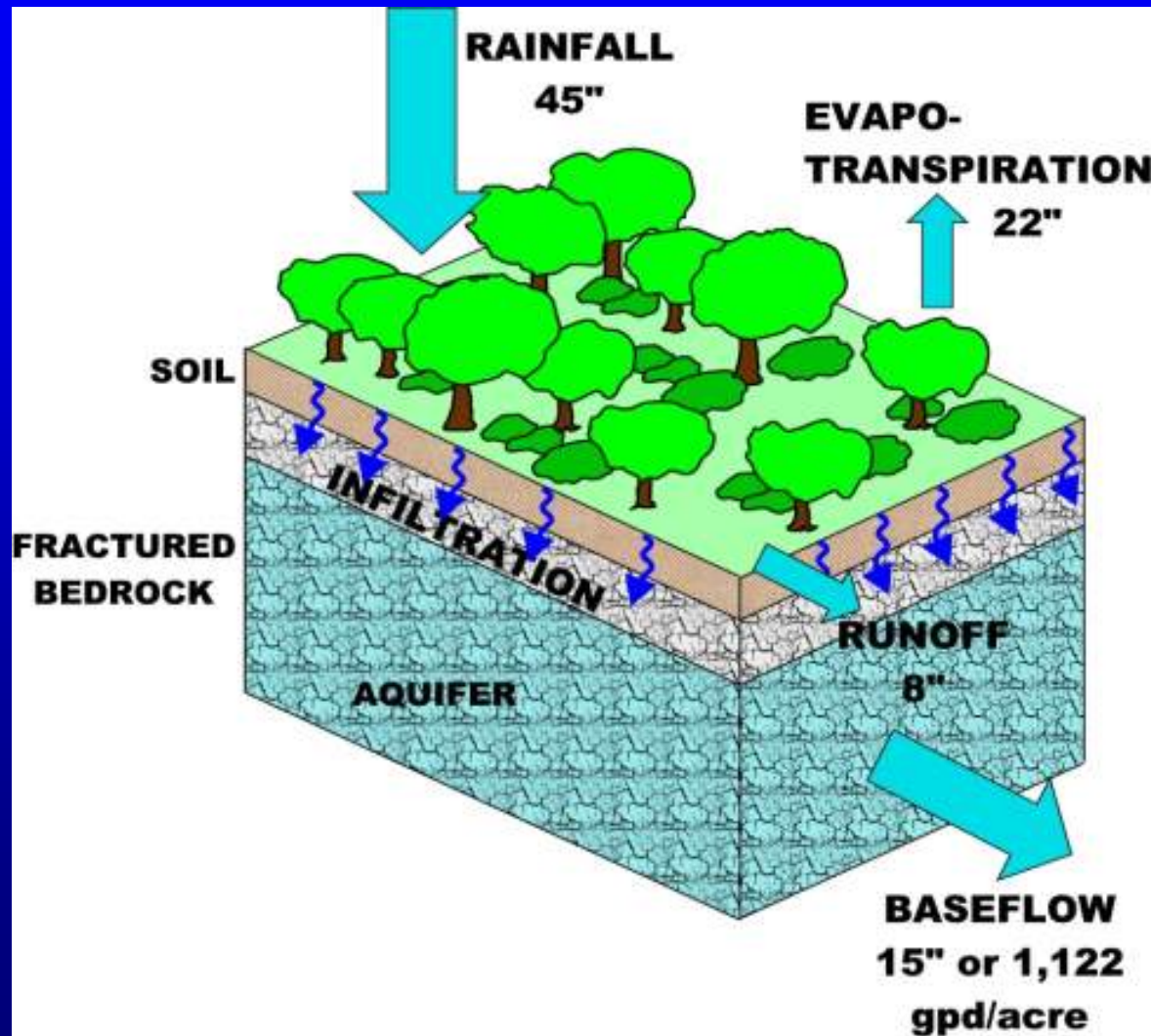


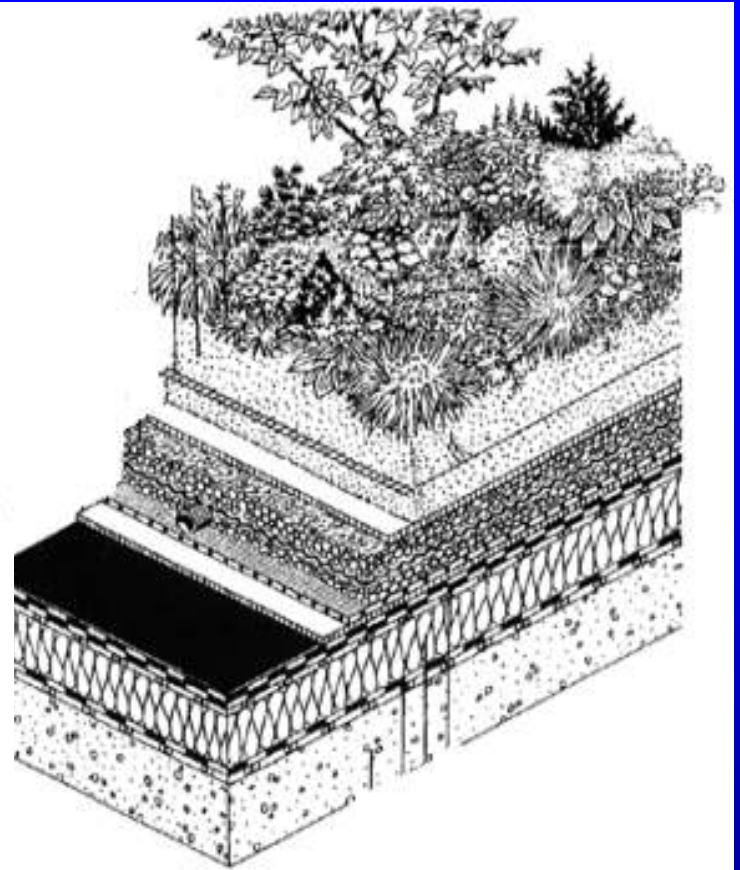
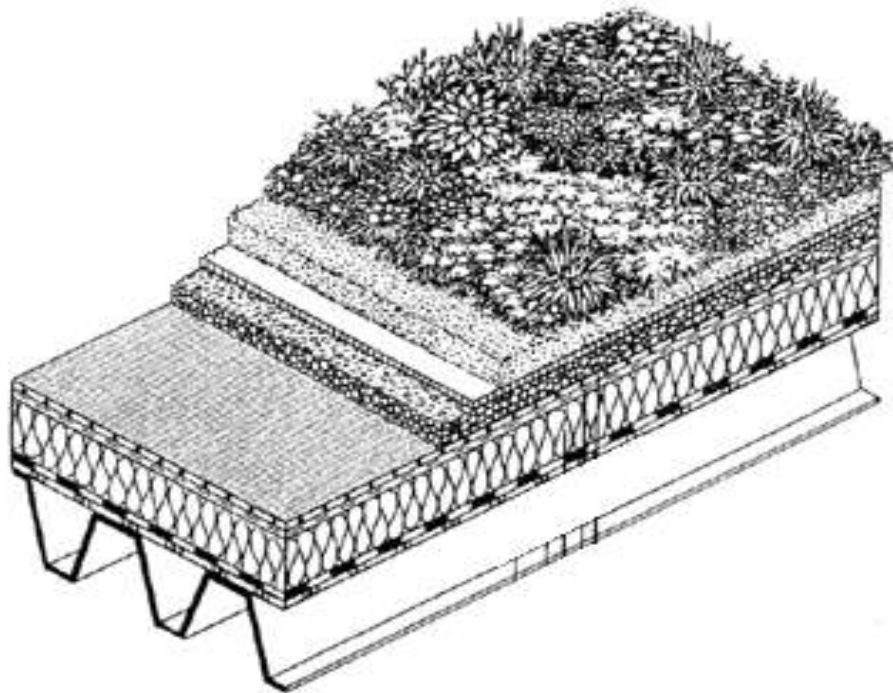
Vegetated Roof Technologies



Annual Hydrologic Cycle

For an Average Year





Roofscapes^{inc.}
Green Technology for
the Urban Environment

Development of Green Roofs

- Original concept in Switzerland – 1970's
- German cities rebuilt after WWII
overloaded combined sewer systems
- Cities mandated green roof systems
- All new buildings with roofs up to 21 deg.
- Cheaper than rebuilding sewers



Willie-Betz Transport Facility

- Over 12-acres of Vegetated Roofs
- Cistern for Firefighting
- Infiltration Trenches and Basins
- Bioswales
- Collection System for Polluted Parking Lot Runoff
- Goal of Zero-Discharge of Stormwater





Simple Vegetated Roof











Parking Garage in Munich





Munich Convention Center

Mienes
Hospital in
Munich
20-years old



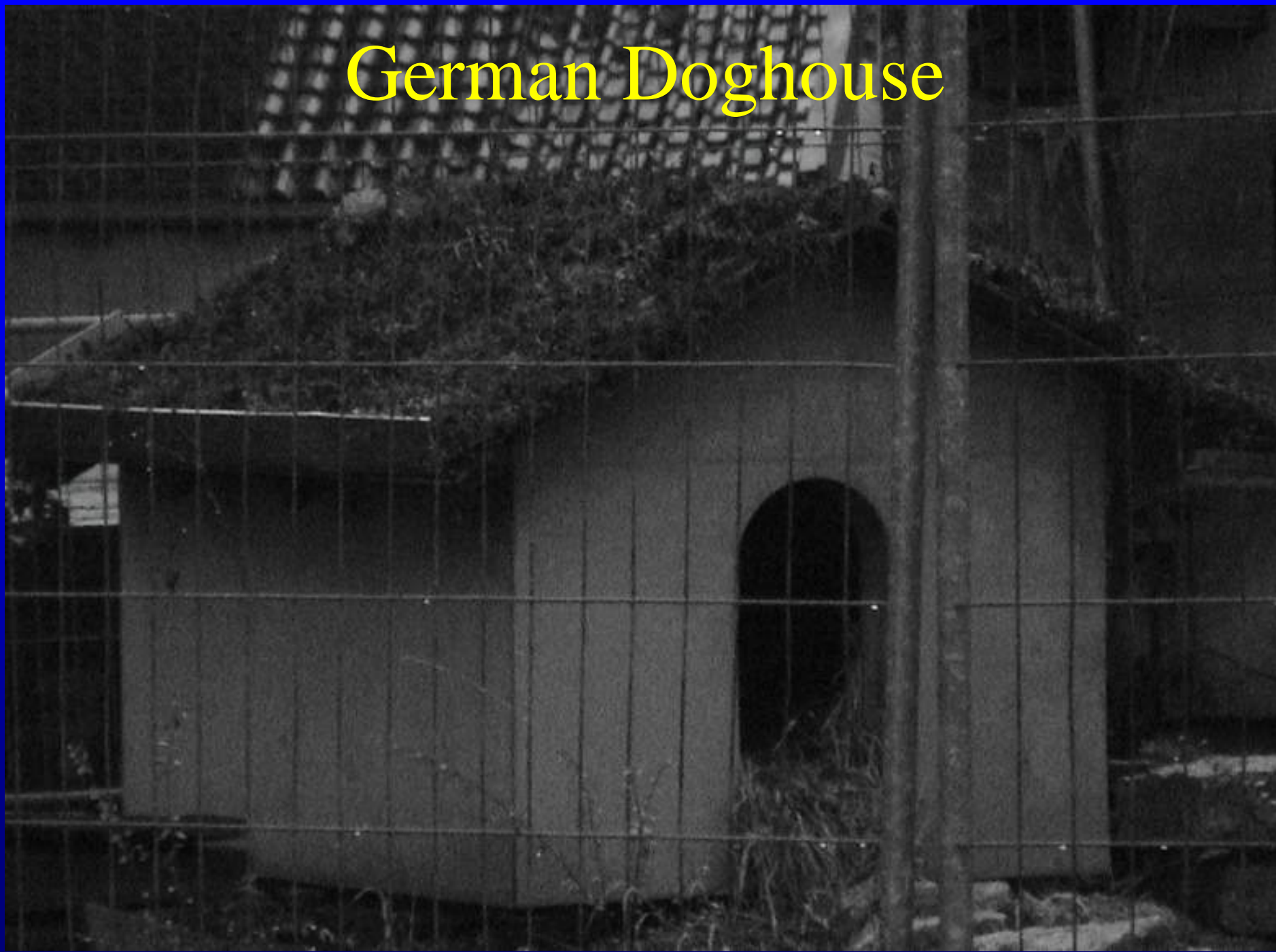


Parking Garage





German Doghouse



Fencing Academy of Philadelphia Roofmeadow™



Before



After



WASTEWATER TREATMENT

ROOFTOP WETLAND SYSTEM







Oslo, Norway – 350 Yr Sod Roof

